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Journal of the
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Proceedings of the American Society of Civil Engineers

CONNECTICUT HIGHWAYS AND THE 1955 FLOODS[a]

Newman E. Argraves,[1] M. ASCE
(Proc. Paper 1621)

ABSTRACT

More than 300 structures, town and state, damaged or destroyed, and more than 2,000 road locations affected by the August and October, 1955, floods in Connecticut required repairs and replacements that called for the expenditure of $38.15 million. Details of emergency and long term restoration are provided in this paper.

Before describing the reconstruction of Connecticut's flood damaged highways and bridges it is well to tell something of the floods and their background of weather.

Friday, August 19, 1955 was the first flood day but the catastrophe was founded on earlier weather conditions. Less than a week before deadly "Diane" visited Connecticut, hurricane "Connie" brought high winds and rainfall ranging between four and six inches in different parts of the State.

As "Diane" moved up the Atlantic Coast it lost its gale force on August 17 and with the reduced danger from damaging high winds the original alert was relaxed. A combination of weather conditions then developed which needs no detailed description here. The important point is that these conditions brought about a period of heavy rainfall starting on August 18 and continuing until the night of August 19. This rainfall broke all previous records. Various locations in the state recorded twenty-four hour totals ranging up to 12.77 inches and at Bradley Field weather station in Windsor Locks the total precipitation from 4 A.M. on the 18th to 3 P.M. on the 19th was 13.97 inches. The previous 24-hour record in 1897 had a total of 6.82 inches.

Even before "Connie" there was some small additional rainfall early in the month which shared in saturating the ground before "Diane" arrived. The

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a. Presented at N.Y. Convention of the American Society of Civil Engineers, October, 1957.

1. State Highway Comm., Hartford, Conn.

total rain from the first of the month through the "Diane" period was 21.3 inches.

All of this is bad enough but the true picture appears when the experience just north of the state line is considered. At Westfield, Massachusetts just 13 miles north of the Bradley Field weather station, the rainfall in the "Diane" period was 19.75 inches. Drainage in Western Massachusetts goes into streams that flow south through Connecticut and it was through Connecticut that the fatal crests moved. The Housatonic River, the Naugatuck River and the Quinebaug River fitted the much abused term raging. The Farmington River, tributary of the Connecticut belonged in the same category. The brooks and smaller rivers in these watersheds also were as deadly as the main streams.

The little Mad River at Winsted, so named because of its noisy turbulence in normal Sprintime freshets, truly earned its name. It moved from its bed paralleling Main Street, ripped up the reinforced concrete pavement of the street like planks on a walk and gouged a channel six or more feet deep in the road bed of the street which, incidentally normally serves to carry U.S. Route 44 through the city.

The areas of worst damage in the August floods comprised the northwestern third of the state and the northeastern group of towns. Elsewhere there was flooding and some minor damage but not the wholesale destruction and large loss of life that characterized the hard-hit areas.

The State was engaged in the clean-up and restoration work following "Diane" when the October storm hit. Its effect was much like the dying hurricane "Diane" but, because it did not start as a hurricane, it was not dignified by a feminine name.

Name or not it was a fearsome storm. Starting early Friday, October 14 it rained almost continuously until early on Monday, October 17. This was two days short of two months after the peak of the August catastrophe.

Housatonic and Naugatuck River areas hit by the earlier flood were again hurt but the second deluge did its worst damage further to the south. In effect the remainder of the western third of the state was sadly ripped and distrupted with further loss of life as well as property.

Connecticut is divided into 169 towns, geographical and political units which account for all of the area of the state.

In 109 of these towns, covering nearly two-thirds of the area of the state, there were roads and bridges destroyed or damaged on the town road system. A total of 215 separate structures and more than 2,000 locations were affected.

On the state's own roads—the state highway system—major road and bridge damage hit another 98 locations. These figures do not enumerate the minor damage areas for reasons that will become apparent.

Repairs of August damage were under way when the October storm hit. Those repairs actually started at the height of the August flood.

In fact, two members of the highway department on their way to start repair work on Friday morning, August 19, died in their truck when the Farmington River tore out the toe of a hill around which the state highway wound. Other floods had passed this point without major consequence. This flood was fatal.

Other maintenance crews like these two men needed no special orders to begin work. When the first wash-outs appeared they began work. It was work that continued, almost without interruption, for days on end. They filled and

graded road and bridge approach wash-outs, removed landslides, erected protective fencing, replaced small drainage structures and placed signs and lanterns for guidance and warning.

The emergency was so great that it became apparent immediately that some of the recovery operations were not covered by any existing statute. The needs required the highway commissioner to authorize work and present the bills for the cost to the General Assembly. It was decided to have contractors do the work on a cost plus basis although there were no provisions for this in the statute. In this way delays were avoided and the state legislature unanimously approved the work and payment for it.

As the seriousness of the emergency became apparent at the height of the flood in August the department headquarters put out radio appeals to contractors and began the compilation of lists of available contractors, their equipment and the supplies needed to restore highway service. It was determined that approximately 200 contractors were immediately available for reconstruction work. In this connection heartening offers of assistance came from such diverse points as San Luis Obispo, California; Rutland, Vermont, and Maryland.

From this time the problems called for decision on temporary trestle bridges or Bailey Bridges were temporary means were urgently required to restore travel. The state's maintenance forces were already at work and nearby contractors were engaged to restore washed out sections that could not be handled promptly by the state's own manpower.

As rapidly as the form of temporary restoration was determined in each instance, the districts secured authorization from headquarters to engage an acceptable contractor to do the work.

The greatest difficulty at the height of the emergency was lack of communication. The damage to the highways and railroads was matched by damage to telephone and telegraph facilities. Radio amateure—the famous "hams" of other catastrophes—were for a time the sole contacts with some areas. Inspection of damaged areas was carried on by helicopter as soon as the "whirlybirds" were freed of the pressing demands of rescue work. Because the department's desire for its own 2-way radio system is soon to be realized, future emergencies will be easier to supervise.

Locations of temporary restorations were checked through the planning division to minimize or eliminate conflicts with future plans or plans already under way. These temporary locations were checked through the Rights of Way Bureau to obtain rights of entry on private property where this was necessary.

The Engineer of Bridges reviewed temporary bridge construction plans before work started to provide H-20 loading, 25-foot width and, where required, 5-foot sidewalks. Typical standard designs were developed to provide temporary bridges and trestles which could be erected promptly on a cost-plus basis. The normal procedure would have required months to design, develop specifications, advertise, award and place under contract any one of the bridges.

Budget allotments were set up by the regular budget machinery and inspection services increased to maintain adequate records of all cost-plus work. Weekly reports on progress of cost-plus and state forces work kept headquarters fully informed.

As these temporary jobs were completed, letters of termination were sent to the contractors, roads were opened to travel and the temporary

detours were discontinued.

While this extensive and pressing program of temporary highway restoration was under way the department was busily engaged in plans for the needed permanent restorations. Estimates were made to determine the entire cost of replacements and the estimates were presented to the legislature at its special flood session.

About this point in time the Connecticut General Assembly met in special session. It made appropriations for the restoration of state and town roads and charged the highway department with the task of carrying out the full program. The law provides that "whenever a state of emergency, as a result of a disaster, exists in the state or any part of the state, and is so declared to be under the provisions of any federal law or state statute, and the highway system of the state becomes damaged as a result of such disaster, the highway commissioner is authorized, notwithstanding any other provision of the statutes, to employ, in any manner, such assistance as he may require to restore said highway system to a condition which will provide safe travel." This became effective December 20, 1955 and was made retroactive to August 19, 1955, the date of the first of the floods. When this session ended in December of 1955 steps were taken to implement the full program.

With the Connecticut Turnpike already engaging more than full time attention it was necessary to look outside for engineering services. The excellent experience of the department with consulting firms working under contract on the Turnpike provided the answer.

Eight firms were placed under contract to handle segments of the town road problem with a ninth firm, Howard, Needles, Tammen and Bergendoff, serving as supervisor and coordinator for the department. Practically all of the operations normally assigned to department field forces were handled by these firms with department personnel entering the individual picture when special problems arose. These firms have carried their projects through to completion of construction. A unit was established in the department to maintain liaison through the coordinating firm of engineers.

In caring for the long term restoration of the state system a slightly different organizational pattern was established. Some of the damaged sites on the state system were at locations which were scheduled for improvement in the long term program of the department and originally they varied widely in urgency. When the flood waters subsided there was no longer any question—they were all urgent, and at the head of the list. Among themselves this group of projects had a sequence based upon the extent of the originally planned project, the adequacy of the temporary replacement, the traffic job of the particular facility and the prospective availability of funds. In some cases planning, survey and design have been delegated to contracting engineers and in other instances these operations are being performed by department engineering personnel.

An illustration of the combined problems of immediate temporary restoration and long-term permanent replacement of a lost facility is provided in the story of the Silvermine River Bridge on the Merritt Parkway.

The Parkway is a four-lane divided highway almost 20 years old. It carries average daily traffic exceeding 30,000 vehicles and has peak periods in the vicinity of 65,000 vehicles. The parallel Boston Post Road has a concentration of traffic which caused the development of the Connecticut Turnpike now under construction. Incidentally the Turnpike will have eight lanes in this particular location.

The October flood undermined the Parkway bridge over the Silvermine River causing it to drop and carry with it several slabs in each of the four Parkway lanes. While this was happening various points along U.S. 1 were hit forcing elaborate detouring of traffic from both the Parkway and U.S. 1. The resulting congestion was fantastic especially on Monday, October 17, when week-end traffic halted by the storm attempted resumption of travel. The four-mile detour for Parkway traffic was so seriously overcrowded at the peak of the emergency that cars were backed up for 15 miles.

Available Bailey Bridges had been largely used up in establishing relief facilities in August and the remaining units had to be spread out to cover a large number of new breaks.

Sufficient Bailey Bridge units were procured to restore the two westbound lanes of the Parkway but units were not available for the two eastbound lanes. A timber-crib design was worked out for the abutments to carry the steel beams borrowed from another project for these two lanes and work of erection commenced immediately. The crews worked around the clock for 60 hours to get the Parkway open.

Obviously the bridge replacement on the Parkway required a by-pass to serve while the construction of the permanent facility was in progress.

Design of the run-around (by-pass) was complicated by the fact that the Parkway enters the rather deep valley of the Silvermine river over hill crests. The Parkway right-of-way had sufficient width to permit a substitute four-lane facility parallel to the existing Parkway. This coupled with the depth of the valley dictated new fill and a temporary stream crossing with an overall length of 2,500 feet. The points of entrance and exit required a design that would not present too sharp a turn with a severe reduction in speed if the substitute was to be useful. The fill for the auxiliary was installed in such a fashion that it will be useable when the state reaches the point of requiring additional lanes on the Parkway.

At the moment the state is erecting the permanent bridge with a wider water area, designed in the light of experience with something new in the way of rainfall and floods. While this work is proceeding the long by-pass is serving traffic adequately.

Connecticut now uses the Bigwood formula for the determination of design flood using five times the mean annual flood as the design flood figure except in special cases. In a few critical areas it is using as high as seven times the mean annual figures.

Many of the other structures destroyed by the floods were much older than the Silvermine Bridge. They had adequate load capacities but their alignments and widths were from another time—a time of limited quantity, slow-moving traffic.

Where these bridges were the property of municipalities their very age imposed special problems. The quiet streets they had served when new, had long since become crowded with motor vehicles.

The state appropriations for the benefit of the municipalities had been established on bases of the cost of replacing by structures of like capacity, with moderate upgrading of standards of lane width and waterway area excepted. Increases in cost caused by expansion of facilities could not be met with state money. The city which, for instance, wanted to provide its principal street with a wider bridge (with additional lanes) was faced with the added cost. It might be well to point out here that the total requests from the

municipalities for restoration and improvements was nearly twice the needs as established under the policy.

The state was faced with the need to secure agreement with the municipality in each such case. These agreements were not simple to secure since conferences were of necessity frequent and numerous and when conferees were in agreement there still remained need for local legislation covering finances. While such activities were in progress the highway department was forced to defer design work on the structure in question.

Steel deliveries presented another problem when it was determined that a year would elapse between the placement of the order and the delivery of the steel. The department sought to procure a priority from the Secretary of Commerce which was denied. Plans were developed to have 50 per cent of the bridges with prestressed concrete decks but the experience was that the state did not get the prestressed decks any quicker than the steel.

With its own roads, the state was not faced with quite the same problem— at least not to the same degree. Many of the state structures were old timers doing an excellent job but definitely not up to modern standards. Some were in the state program for replacement soon and some were planned for future years and future funds.

Obviously replacement of some on the same site was unwise. Some were located at right angles to the streams they crossed and had approaches with sharp curvature. These substandard alignments called for modernization. The destruction of the bridges hastened the initiation of the general improvement of which a new bridge would be a part.

Where the department could only expend the appropriation total for the towns it could adjust its own remedial work to merge flood replacement and general improvement funds to the benefit of the state and its highway system.

All but 9 of the 215 town bridges that were put out of business by the floods had been rebuilt or were under construction in October with completion due soon.

Two of the 9 bridges - one each in Ansonia and Norwalk - were held up pending decisions by the cities concerning the new bridges and local redevelopment plans. The planning phase was completed and both bridges are under contract for completion in the next construction season.

The other 7 were not put under construction earlier for various reasons, for instance some were combined with projects on the state highway system. Two were held over to minimize traffic dislocation.

Where the state's own bridges were concerned the department's planning division made a thorough study of each location to assure full consideration of other highway deficiencies at each location. Thus all replacements will have alignments, gradients and roadway width consistent with the demands of modern motor traffic.

The importance of many of the damaged locations on the state system is indicated by the fact that of the 98 locations with damage heavy enough to warrant repair or replacement under contract there were 72 locations on those parts of the state system incorporated in the federal aid system of highways. Thus, in many instances federal aid primary, urban or secondary funds are available for parts of the new facility.

It is expected that all but 12 of the projects on the state system which are principally flood projects will be completed this year. The remaining ones are parts of major improvements that have a gross value of more than

$10,000,000 of which less than $3,000,000, represents the flood restoration share of the work. At points where permanent replacements are not in place there are temporary facilities which give good traffic service.

The total flood fund allocations give a dollar picture of the magnitude of the job. Town projects required $17.15 million and state projects another $21 million. It has kept the department busy because at the same time we have been in the midst of the work of building a Turnpike costing another $460 million as well as planning and putting under contract an accelerated program which moved from the approximately $16 million of former years to more than $40 million. The department was also getting under way the program established by the 1956 federal aid highway act and performing normal maintenance on state roads as well as on the annual program of town aid to the 169 towns.

Shortly after the first flood receded the state highway department placed its entire town aid organization, including supervisors, at the service of the U.S. Army Engineers. In this way the Army group was able to work closely with the authorities of the affected towns.

Fine cooperation with the department marked the efforts of both the Federal Bureau of Public Roads and the Army Engineers.

Out of this disaster cam an unparalleled opportunity to study, on a full-scale research basis, the adverse effects of flood waters and to insure the adequacy of the foundation design. A complete paper on the subject was reproduced in Highway Research Board Abstracts for September 1957.

This is the story of recovery from two disastrous floods in as many months. Thousands aided in rescue and hundreds labored on the restoration work. Their efforts have built a better Connecticut out of the tragedies of August and October in 1955.

(Photo courtesy of Howard Birch and the Waterbury (Connecticut) American)

Devestation along the banks of the Naugatuck River in Waterbury, Connecticut. following the flood of August 19, 1955 and succeeding days.

(Photo courtesyoof Hank Murphy and the Hartford (Conn.) Times)

Main Street, Winsted, Connecticut, after the flood waters of August 19 and 20, 1955 had receded. Route U. S. 44 uses this street in going through the city.

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THE ROLE OF THE STATE IN THE HIGHWAY PROGRAM[a]

Rex M. Whitton,[1] M. ASCE
(Proc. Paper 1622)

ABSTRACT

The role of the State in carrying out the expanded federal-aid highway program is multiple, of initiative and cooperation, as public informer and guide, as planner of programs and developer of locations and plans, as acquirer of right of ways, as supervisor of construction, and as maintainer of the finally achieved system. State Highway Departments must see that the individual states get maximum benefits within the state yet make certain the state pattern fits into the national system in the best possible fashion. Because basic responsibility for success of the highway program lies with the state, highway departments need take the lead in providing public support for it and need keep their own house in order to maintain good public relations and give full value to the public in highways built.

The role of the State in carrying out the expanded federal-aid highway program is clear and specific, not only as it concerns the Interstate System in urbanized areas but also as it applies to all highway system types. It is a multiple role—of initiative and cooperation, as public informer and guide, as planner of programs and developer of locations and plans, as acquirer of right of ways, as supervisor of construction, and as maintainer of the finally achieved system.

This is not a new role for the State. Rather, it is quite an old one. For the most part it dates back to 1916, when the initial Federal Aid Highway Act was adopted by Congress. One needs but review that 1916 Act to find most of the

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a. Before American Society of Civil Engineers, Highway Division, New York City, October 15, 1957, Panel Group on "The Interstate System in Urbanized Areas—an Administrative Problem for all levels of Government."

1. Chf. Engr., Missouri State Highway Comm., Jefferson City, Mo.

activities and obligations mentioned spelled out for the State through its highway department.

Section 6, for example, says, among other things:

> "Any State desiring to avail itself of the benefits of this act shall, by its State Highway Department, submit to the secretary of agriculture project statements setting forth proposed construction of rural post roads or roads therein. If the Secretary of Agriculture approves a project, the State Highway Department shall furnish to him such surveys, plans, specifications and estimates therefor as he may require . . . the construction work and labor in each State shall be done in accordance with its laws and under the direct supervision of the State Highway Department . . . the Secretary of Agriculture and the State Highway Department of each State may jointly determine at what times and in what amounts payments, as work progresses, shall be made under this act."

Section 7 of that same 1916 Act also says this:

> "To maintain the roads constructed under the provisions of this Act shall be the duty of the States, or their civil subdivisions, according to the laws of the several States . . . If at any time the Secretary of Agriculture shall find that any road in any State constructed under the provisions of this Act is not properly maintained he shall give notice of such fact to the Highway Department of such State . . ."

The charge in this 1916 Act fixed the policy that initiative and planning lies with the State. The rules or obligations as they concern the State Highway Departments have been little changed through the years.

Now, of course, we answer to the Department of Commerce through its Bureau of Public Roads in carrying out Federal Aid Highway Requirements, rather than to the Department of Agriculture. But, insofar as the rest of the program is concerned, we face the same requirements now as we did in 1916 —initiative and cooperation, public informer and guide, planner of programs and developer of locations and plans, acquirer of right of ways, supervisor of construction, and highway maintainer.

If we are to play our role successfully in this vast new road-building drive, we should first direct our efforts to complete cooperation and unity with the Bureau of Public Roads.

Traditionally, of course, highway construction, maintenance and financing have been primarily a state and local responsibility. We cannot deny, though, that vast strides in highways have been made since the federal government became a partner in our effort. Because of the federal participation, for example, we have been assured of an integrated highway system.

The Bureau was set up originally as a guardian to see that federal monies were spent to achieve maximum benefits. Certainly only by achieving maximum benefits can we hope to attain adequate highways for our urban areas and our State as a whole. We have a common purpose, so cooperation and unity should follow easily. And, with huge additional funds available to us, undoubtedly we can best attain the utmost in benefits by joint effort.

Next, let's consider the State level. There every effort should be made to maintain a close liaison with members of the General Assembly or State Legislatures and with the various State officials.

We in Missouri have, as do you, basic and fundamental laws governing the

highway program and highway administration. But, to keep pace with modern trends, and year to year needs in providing a complete highway program for highway users, it is imperative these basic laws be supplemented from time to time. Only by having informed legislators can we be sure the necessary supplemental actions are taken.

One of the first steps toward maintaining a desired close liaison at the legislative level is through personal contact. That necessarily will be spearheaded by the Chief Engineer or top administrative official of your Highway Department, and supplemented by other department officials, including the Commission.

In Missouri, for example, we always seek to maintain close personal contact with our state officials. Frequently, during sessions of the General Assembly and even when it is in recess our officials and commission members confer with legislative leaders and appear before committees or commissions to discuss the highway problems and solutions, with much attention given to policies. For example, when we launched our 10-year State Highway Modernization and Expansion Program in 1952 our Commission filed with the legislature a statement of its policy if the program were adopted. We are now engaged in carrying out aims and purposes stated therein.

Also, during the past several years, we have submitted to members of our General Assembly copies of all news releases issued concerning any highway work in their respective areas, as well as all general releases concerning highways.

As a result of these efforts in the past few years we feel we have brought about material improvement in our relations with the General Assembly and a better understanding on its part of the State's Highway problems, and plans of the Highway Department to solve them. All this has moved us forward toward meeting today's highway needs.

Moving on to our role within the urbanized area we here again have a responsibility for a close liaison and cooperation within the area. There the State Highway Department should direct its efforts, through all types of cooperative action, meetings, conferences and joint effort with City and County officials, to develop a highway system which will meet the needs of the area and with which most people will be in accord.

Traffic congestion today is without doubt a pressing problem for most cities. As it has become more and more acute it has resulted in a vast change in the settlement pattern of those cities, with the trend being toward urbanization—pushing out of the cities into the urban areas. As we consider our role in carrying forward the Interstate System through these urbanized areas it should be our purpose to coordinate our highway planning with city and regional planning to the end that the entire urban area will have orderly development and obtain the maximum benefits.

We must design new planned access highways so they will stimulate growth of the community in the years to come. This will come in development of master plans for the communities which take into account the various land use types—governmental, residential, commercial, industrial and recreational, all coordinated with the various types of transportation.

As we develop these master plans we must keep the urban area officials and peoples advised of our methods and why we do this or that. We should confer with them to get their ideas on which should be done and, where possible, incorporate those ideas into our planning. We must not overlook the chance to advise cities and counties that these new Interstate Routes offer

them real opportunity to combine traffic relief with slum clearance and with halting of blight and declining land values. Also, they will provide the means of speedy evacuation of an urbanized area in time of peril.

With a master plan developed for the urbanized area we should present it to local authorities, then spare no effort to see that they thoroughly understand it. We should visit civic groups and civic leaders to explain the plan and what it should accomplish. Our every effort should be made to develop the feeling of comradeship and trust, of singleness of purpose—to benefit the community and the state as a whole.

No discussion of highways, and particularly one concerning the role of the State Highway Department, would be complete if it did not give some thought to the right of way problem we face. This problem has become especially complex in the urbanized areas where, in effect, highway improvement has developed into a veritable race between construction of the highway and industrial or residential development of the area through which the highway passes.

In recent years that situation has become so acute that at times now we may go into an area and make the initial survey for a section of highway. Then, by the time we can complete necessary preliminaries and designing and return to acquire right of ways we'll find a factory or 200 or 300 homes on the needed land. The result? Spiraling right of way costs.

Design demands for the highways of today have contributed to complexities of our right of way acquisition activities. Modern highways, for example, now require up to 300 feet of right of ways as against 60, 80 and 100 of Model T days. Now we must have space for divided pavements, wide shoulders, wide median strips, outer roadways and, in many instances, acreage for cloverleaf or other large interchanges, and access rights to permit control of access.

As we seek the larger land tracts for such facilities we come face to face with a lack of understanding on the part of the public on the values and economic effect of a highway of this type. As a result of that lack of understanding too often we are rapped with excessive awards for taking the land needed.

Again, with such a huge highway building program before us, we are faced with a wave of land speculation, especially in urban areas. In many instances our announcement of the tentative location of a new highway, or the modernization of an existing route has brought quick surveys and filing of plans for subdivisions. Speculators also frequently attempt to turn a quick dollar by picking up bargains on property needed for right of ways in advance of our acquisition efforts.

We, in Missouri, have directed all our efforts to obtain land we need at a minimum of cost, and as near a reasonable market value as possible. We employ reputable appraisers to make written reports on land values. Our officials then study the property and the appraisals and fix a top value on each. The right of way agent then contacts the property owner and attempts to make a deal. We know the property owner is entitled to a fair price but, if we can not obtain the property at the top value we have fixed we then resort to condemnation proceedings.

As we move to meet these right of way problems perhaps our role again should be that of striving for public understanding. If we can gain greater public understanding of the value of these highways we are building, perhaps in turn the public approval developed for the program will create pressure on those who would delay or rob the program by boosting right of way costs beyond all reason and minimize this obstacle.

The impact of this Interstate Highway System program will be felt in the Nation's urban areas for many years to come. It will, of course, have great bearing on area economy. For cities which cooperate to the utmost it will provide for civic face-lifting and show the way for redeveloping run down areas. It will stimulate industrial and residential development. It will promote greater traffic safety and above all it will decrease traffic fatalities.

Overall, the program, through its expanding highway network, will set in motion a chain of events for urban areas that will promote orderly community growth, readily available markets, more industries, more jobs. Through accomplishing these things it will open the way for area residents to more complete enjoyment of recreational and cultural resources.

The impact on urban economy is seen quickly when one notes that about half the $25 billions authorized for Interstate System Highways during the 13-year program period will be spent in urban areas. Construction of these highways, of course, is a basic activity. It will stimulate a demand for more materials, machinery, equipment which, in turn, will result in enlargement of production facilities and the creation of more jobs with resulting benefits to the urban areas in which they are located.

The civic face-lifting will come in slum clearance projects and redevelopment of run down areas that may be fitted to the new highway pattern. It also will come in industrial and residential development, which in turn will boost area property values. At the same time downtown areas will benefit through increased efficiency of city streets as non-stop traffic is siphoned off, thus providing more parking space and congestion relief.

Human lives will be saved. Experience on highways of the design type of the Interstate Route already is conclusive as to its increased safety. Dollar values cannot be placed on lives saved and injury and suffering prevented. Neither can we measure with any exactness the savings within urban areas. Nationally, however, some place these savings at $725 millions annually on a national basis, with a relatively high percentage certainly to be within the urban sections.

We pay for good highways whether or not we have them. The expanded Federal Program offers us the opportunity to at least improve on what we have. Very definitely the role of the State Highway Department is to see that the individual State it represents gets the maximum benefits out of the program within its State, not only in the urbanized areas but throughout the entire State, and to see that that particular State fits its road pattern into the national system in the best possible fashion.

The basic responsibility for success of the highway program lies with the State. We must not hesitate to shoulder that responsibility and take the lead in providing public support for it. We must keep our own house in order, with an alert, vigorous, efficient department, we must maintain good public relations and give full value to the public in highways built.

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GROUND TRANSPORTATION AT NEW YORK INTERNATIONAL AIRPORT[a]

Richard I. Strickland[1]
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ABSTRACT

A new concept in airport terminals resulted in a 655 acre "Terminal City" which will include 10 passenger terminal buildings, 10 miles of 2 lane roads and multiple parking facilities. Basic planning data is presented; design of the roadway system and parking facilities to meet the needs of airport users is discussed.

A New Concept in Airport Terminals

Later this year a sparkling new Terminal City covering 655 acres will be opened at New York International Airport. When completed the development will include 10 miles of two-lane roads, 4 parking areas providing over 6,000 spaces, a 220-acre International Park, and 12 separate major buildings. The $120,000,000 Terminal City will be an exciting and functional treat for the millions of air passengers who use this aerial gateway to the United States.

The early planning for a passenger terminal to replace the temporary terminal, which was opened in 1948, visualized a large central building. However, as planning advanced and the future level of activity at the airport was considered, it became obvious that the number of plane positions required could not be functionally located around a single building. The logical solution, then, became the establishment of multiple terminal buildings. The new terminal plan was welcomed by the airlines operating from New York International Airport. This total now includes 14 United States flag airlines and 17 foreign flag airlines. The new terminal plan enables the larger United

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1. Asst. Chf., Traffic Eng. Div., The Port of New York Authority, New York, N. Y.

States airlines to have their own separate terminals and provides the foreign flag airlines with separate, ample ticket offices and lounges.

Fig. 1 shows an artist's concept of the completed Terminal City. The largest structure is the combined International Arrival Building and Airline Wing Buildings which will be opened later this year. The International Arrival Building is the U-shaped, central portion, and will provide facilities for all arriving planes from overseas points requiring Federal inspection services. Incoming passengers will use the ground floor of the two arcades, or fingers, and move directly to Federal Health, Immigration, and Customs inspection services. They will then exit to the street and ground transportation using only the ground floor of the building. The long fingers to each side of the I.A.B. are the Airline Wing Buildings where the ticket counters, lounges, and offices of the foreign flag airlines are located. Outgoing overseas passengers will arrive at the ticket offices in the Wing Buildings, directly from the street, and then proceed to the second floor level on their way to aircraft loading gates. The combined length along the roadway system of the International Arrival and Wing Buildings is about 2,300 feet or over 11 city blocks. To visualize the length of this building, it can be imagined to extend from Macy's at 34th Street into the heart of Times Square, or crosstown from 7th Avenue to 5th Avenue.

The remaining terminal buildings located around the central roadway system will be unit terminals, operated by various United States airlines. Construction of several of these terminals will be started in 1957 and in a few years the Terminal City will have 6 passenger terminal buildings. At that time it will be possible to provide 140 aircraft loading positions.

To indicate the function of New York International Airport in serving the New York City area, Fig. 2 outlines the regional airport system for the northern New Jersey-New York region. The Port Authority, as the agency of the States of New York and New Jersey, finances, develops, and operates the 4 major airports shown in Fig. 2. The region, the principal airport traffic center of the United States and the air crossroads of the world, handled over 12 million passengers in 1956, including more than 1.5 million overseas air travelers. In the regional system, New York International Airport handles all of the region's overseas air traffic as well as a significant share of the domestic traffic. La Guardia Airport and Newark Airport handle domestic passenger flights only. It is anticipated that Teterboro Airport will continue to handle the increasing, important volume of business aircraft as well as training and private flights.

Coming back to New York International Airport, Fig. 3 is a map showing its important features. The area of the airport is almost 5,000 acres, 9 times the size of La Guardia Airport, and equivalent to all of Manhattan Island from 42nd Street to the Battery. The major artery into the airport is Van Wyck Expressway, which has a complete interchange with Southern Parkway on the north side of the airport and extends north to the Kew Gardens interchange with Grand Central Parkway and Interboro Parkway. The limited access nature of Van Wyck Expressway is continued into the airport and taxiway and roadway underpasses have been provided to bring it into the central terminal area. The other principal access road is 150th Street, which is used predominantly by employees, and cargo and service vehicles. Future highway plans call for a Nassau Expressway along the northern boundary of the airport with connections to Southern Parkway and Van Wyck Expressway. The airport is unique in having a subway station of the New York City Transit System along

its western boundary. Prominent in the figure are the many hangar developments. There now are, built or under construction, 13 hangars, and several more are in the planning stage.

Fig. 4 shows recently built cargo buildings. This development of 4 buildings, providing direct transfer of cargo from airplane to truck, was recently completed to meet the demands of the rapidly growing volume of air cargo. The buildings are leased in sections, so that each airline has its own plane apron, truck apron, and employee parking space. The fifth building in the center of the development is a cargo service building, providing temporary warehousing and shipping services.

Looking at the scope of the development at New York International Airport, you can realize the complex nature of the planning required. The Traffic Engineering Division was just one of the many groups participating in the planning of the central terminal area. Under the Port Authority Commissioners and the Executive Director, the Aviation Department has the overall responsibility for the development. The Planning Division of the Aviation Department drew upon airline experts, architectural and engineering consultants, as well as several departments of the Port Authority. The final plan is the result of much effort, many conferences, and much coordination among the many interests involved.

Ground Transportation Planning Data

A basic step in the planning of new facilities for New York International Airport was the collection and analysis of airport operating data and the prediction of future requirements. This was the responsibility of the Forecast and Analysis Division of the Aviation Department. Their analyses ranged from complex studies, such as the prediction of the U. S. domestic air passenger market from the present to 1975, to detailed analysis as to parking and traffic needs of the airport. In passing, it is quite awakening to note the forecasted growth of air passenger volume. Compared to 1955's total of 38.7 million domestic originating trips in the U. S., it is expected that in 1965 this figure will increase to 90.0 and in 1975 to 167.0. Air travel is expected to more than quadruple in the next 20 years. Some of the information which has been gathered concerning ground transportation is presented to indicate the requirements that had to be met at New York International Airport.

A first consideration is the makeup of the population at an airport. Table 1 indicates the percentage breakdown of the population in the terminal area at New York International Airport.

Table 1

Terminal Area Airport Population
New York International Airport

Passengers	56%
Visitors with Passengers	23
Sightseers	5
Employees	11
Others	5
	100%

Source: Survey of the Market for Consumer Goods and Services, Spring 1953.

Air passengers constitute only a little over half of the persons in the terminal area. Sightseers, while averaging the five per cent indicated, will constitute a much greater percentage of the population on weekends. The degree to which consumer services are supplied at airports can affect the population. At Newark Airport it has been found that 12% of the vehicles using the parking lot are diners. Employees in the terminal area are about 10% of the terminal area population and about an equal number of employees are located outside the terminal area.

As to the transportation this population prefers to use, Table 2 presents a study of the mode of transportation used by employees. Note that those driving their own cars or riding in someone else's car total about 88% of the employees. The ratio of employees per car is about 1.2, indicating minimum usage of car pools. Although employee population is probably less than 20% of the total airport population, it must be considered in highway capacity as shift changes cause heavy peak flows.

Table 2

Employee Mode of Ground Transportation to N.Y.I.A.

Drove own Car	71.8%
Came in another Employee's Car	13.4
Dropped off by car	1.3
Used public bus	11.2
Came in company car	1.0
Other	1.3
	100.0%

Source: Survey of Airport Employees, Friday, July 8, 1955.

Turning from employees to air passengers, Table 3 summarizes the mode of transportation used by outbound domestic air passengers at the three major Port Authority airports in the year November 1955 thru October 1956. This information was taken from an extensive in-flight survey made by the Port Authority with the cooperation of the commercial airlines. Domestic passengers are defined as those having destination on continental United States, Mexico, or Canada. The tabulation does not include transfer passengers who come in on one flight and switch to a different outgoing flight at the same or other airport in the New York area. Transfer passengers represent about 20% of total air passengers.

Table 3

Outbound Domestic Air Passenger
Mode of Ground Transportation to Airports
(Excludes Transfer Passengers)

	Auto	Taxi	Airport Coach	Public Bus
N.Y.I.A.	42%	26%	31%	1%
La Guardia	37	41	20	2
Newark	46	12	38	4

Source: Domestic In-flight Survey, November 1955 - October 1956.

Usage of ground transportation at New York International Airport represents an approximate median between that at La Guardia and Newark. The different usage rates at the various airports result from several factors such as location, type of flight, closeness to Manhattan, and the type of travel. For example, La Guardia Airport is the closest to Manhattan and has the largest use by business type travelers resulting in a heavy use of taxis in reaching the Airport. Newark experiences the greatest use of airport coaches because it is further from the center of population concentration and good highway connections serve New York City. The small use of public bus by air passengers is noted. The importance of passenger cars in transporting air passengers is indicated by the total of auto and taxi use which varies from 58% to 78% at the three airports.

Table 4 provides further insight into the variation in the use of ground transportation to airports. The usage rates are broken down by resident and non-resident users. The Metropolitan area includes counties in New Jersey, Long Island, and north of New York City as well as the five boroughs of the City. With non-residents, the use of private autos is less than half of that by residents, and taxis and airport coaches are used in greater degree to reach the airport.

Table 4

Outbound Domestic Air Passenger
Mode of Ground Transportation to N. Y. I. A.
For Residents and Non-Residents of the Metropolitan Area
(Excludes Transfer Passengers)

	Auto	Taxi	Airport Coach	Public Bus
Residents	58%	20%	21%	1%
Non-Residents	25	32	42	1
Total	42	26	31	1

Source: Domestic In-flight Survey, November 1955 - October 1956.

Table 5 shows the variation in use of private cars for different type flights at New York International Airport. A greater number of cars must be accommodated in the parking lots for overseas flights. This is even more apparent from the domestic flight figures for La Guardia Airport, where domestic coach flights generated six parked vehicles and domestic regular flights only three parked vehicles compared to the average of nine for overseas flights at New York International Airport.

Table 5

New York International Airport

Type of Flight	Parking Lot Cars per Flight
Domestic Coach	5
Domestic Regular	6
Total Domestic	6

Type of Flight	Parking Lot Cars per Flight
Overseas Tourist	8
Overseas Regular	10
Total Overseas	9

Source: Survey of Public Parking Lot Patronage, August 1953.

In designing the roadway system to serve an airport terminal development, it is especially important to know the manner in which airport motorists wish to use the terminal and parking facilities. Table 6 summarizes observations made at the terminal areas of the three major airports during 1955 and 1956.

Table 6

Distribution of Cars Entering Terminal Area

	Design	Range
Direct to Parking Facility	65	60-75%
To Terminal then to Parking	10	5-15%
To terminal then Exit	25	15-35%
Distribution of Cars Leaving Parking Lot		
Exit Directly	90	75-95%
Stop at Terminal	10	5-25%

Source: Traffic Studies, Summer 1955 and 1956.

As indicated, it was found that the majority of the vehicles approaching a terminal area desire to go directly to a parking facility and only 10% wish to stop at the terminal before parking. Therefore, provision of direct access to parking facilities will relieve terminal frontage roadways of a majority of the traffic which would otherwise pass the terminal. Leaving the parking lot, motorists again predominantly did not desire to stop at the terminal, and 90% exited directly from the airport.

Information on the parking habits of airport motorists is also important. Table 7 summarizes the use of the three New York airport parking lots by purpose of visit on an average day. In this comparison those parking while dining were excluded to provide a better basis for comparison. This is not to say that diner parking should be disregarded, because, as mentioned before, this parking might represent over 10% of parking lot users.

Table 7

Composition of Parking Lot Volumes on an Average Day by Purpose of Visit at La Guardia, New York International and Newark Airports

	Per Cent Distribution Airport		
Purpose of Visit	La Guardia	N.Y.I.A.	Newark
All Purposes	100%	100%	100%
To Transport Air Passengers	75	70	66

Purpose of Visit	La Guardia	N.Y.I.A.	Newark
To Airport	30%	28%	32%
From Airport	30	38	20
Duration Parking	15	4	14
To Transport Sightseers	10	18	16
To Transport Others	15	12	18

Source: Survey of Public Parking Lot Patronage, N.Y.I.A. and LAG—August, 1953; Newark—June, 1954.

The bulk of parking lot usage is generated by the transportation of airport passengers and ranges from 65% to 75% of parking lot volume. The next greatest generator is sightseeing which constitutes about 15% of the parking volume on an average day. On a weekend, sightseeing volume rises sharply, and studies at Newark Airport showed a rise to over 20% on Saturday and over 25% on Sunday. Special note should be made of the approximately 15% of parking lot users at La Guardia and Newark that parked for the duration of their air trip and this will be discussed further in connection with the next table.

In Table 8 is summarized the duration of parking for the various purposes of visit at the three airports. It is important to note that the average shown for all purposes does not include the duration parking just mentioned.

Table 8

Average Duration of Parking for Cars, By Purpose of Visit, On An Average Day at La Guardia, New York International and Newark Airports

	AIRPORT		
Purpose of Visit	La Guardia	N.Y.I.A.	Newark
		(Hours)	
All Purpose*	1.5	1.6	1.7
To Transport Air Passengers:	1.2	1.6	1.2
To Airport	1.2	1.4	1.2
From Airport	1.2	1.7	1.1
Duration Parking (Days)	(1.8)	(4.8)	(2.0)
To Transport Sightseers	1.4	1.3	1.0
To Transport Diners	-	-	1.7
To Transport Others	2.1	1.9	3.6

*Average duration of parking is computed only for cars parked less than one day.

Source: Same as Table 7.

While parking for most purposes averaged between 1 and 1.7 hours, duration parking averages between 1.8 and 4.8 days. The average duration parker at New York International Airport requires the same space hours in the parking lot as 72 parkers carrying passengers to or from the airport. The La Guardia Airport duration parker averaged only 1.8 days. This still represents the parking lot space required by 36 vehicles used to carry air passengers to or from the airport. The effect of duration parking on parking lot

congestion was recently shown to us forcibly when a check at Newark Airport found an inventory of 500 parked cars at 3 a.m. in a lot of 640 car capacity.

Roadway System

An airport roadway system must serve several functions. Probably the most important function is to provide direct access to the passenger terminal area. As mentioned previously, the Van Wyck approach into the airport is of limited access with grade separations provided at taxiways and intersecting roadways. To provide for the increased activity at the airport in the future, 150th Street is also being developed to serve as a limited access route to Terminal City. It will be dualized and an overpass will be provided to directly connect it to the Terminal City loop. Underpasses are planned for the taxiways now crossed at grade.

A second function of the roadway system is to provide good access to all areas of the airport. To allow access to hangars and service facilities located along Van Wyck Expressway, it was necessary to provide 24' wide, two-way service roads on each side of the Expressway. These roads are connected by a loop overpassing Van Wyck at one end and a traffic circle at the other. Entrance from the service roads is possible only at these extremities, more than a mile apart. An intermediate exit is provided from Van Wyck to the northern service road.

A similar design for service roads was found necessary for the future development of 150th Street. Service facilities along this road such as those for air cargo, in-flight meal preparation, and airport coach maintenance, will generate peak traffic volumes that will rule out grade intersections and warrant service roads with a connecting overpass.

The roadway system should allow separation of truck traffic, destined to airport service areas, from passenger terminal traffic. Air cargo trucks to New York International Airport are now diverted from Van Wyck Expressway at the airport entrance and reach the cargo development via 150th Street.

The service roads of Southern Parkway, North and South Conduit Boulevard, provide convenient connections between Van Wyck Expressway and 150th Street. It is also planned to provide a separate access route to serve an industrial area now under development in the northwest section of the airport. Thus, Van Wyck Expressway will not be required to carry all the traffic generated by the industrial area. A special problem at New York International Airport has been the flow of ramp service vehicles, such as fuel trucks, food trucks and baggage carts, to and from the plane aprons of the various terminals. An entirely separate roadway has been provided for these vehicles, completely circling the Terminal City development. The peripheral road will carry two-way traffic and provide direct and convenient service to all apron areas. Connections to Van Wyck Expressway and 150th Street will be controlled to prohibit use by the general public.

Within Terminal City, the roadway system must allow convenient access to each of the terminal buildings as well as to the parking areas serving these terminals. Fig. 5 shows a map of Terminal City with the roadway system which was developed to provide this necessary access. Terminal City includes 4 principal public parking lots, each one associated with a group of terminals. Entering the terminal area from Van Wyck Expressway at the lower right corner of the picture, a separate route is provided to reach each of these four

areas. For example, traffic to the Lot 1 area exits first to the terminal loop. Traffic to Lot 2, which serves the International Arrival Building, is next taken off just beyond the service station. Lot 3 traffic next turns off to the left to the two terminals at the bottom of the picture. The remaining traffic is destined to Lot 4 area at the left side of the picture. Exiting from the parking lots or leaving the terminals, similar separate routes are possible to reach Van Wyck Expressway. Thus mixing of traffic to and from the various terminal areas is kept to a minimum within Terminal City.

Design standards for the roadway system are much the same as current practice. With the exception of the inner service roadways at the terminal buildings, the roadways are all two lane, 24' wide roadways. Mountable curbs and 8' stabilized shoulders are provided. All roadways carry one-way traffic and no direct crossing of traffic streams is permitted. Intersecting traffic streams are guided to merge and diverge to perform the turns required to reach terminal and parking areas. The width of the center mall between the one-way loop roadways is 100', so that the principal turnarounds have an inner radius of 50'.

One of the most difficult design specifications to maintain was that of providing a 300' weaving distance between a major entrance and exit of the terminal loop. For example, a motorist leaving one of the parking lots and seeking to reach a terminal building across the mall, is guided to merge with the loop roadway and then cross-weave in a distance of 300' to reach a turnaround roadway to the terminal site entrance. Because of the number of terminals and the access connections which had to be provided to each, it was found necessary to accept somewhat less than 300' as weaving distance in several cases.

An associated problem to which study is now being given is the design of the roadway connections to the unit terminals from the terminal loop. Terminal City planning had visualized a single inner service road at ground level at each of these terminals. However, several of the airlines have submitted building plans requiring roadways at two levels. Careful design will be necessary to maintain weaving distances on the loop roadway and minimize roadway grades for unit terminal connections.

Within the terminal area, pedestrians must be accommodated as well as vehicular traffic. The most desirable solution to the conflict between these two movements would be the complete grade separation of the two. At the IAB, as you have noted, a central pedestrian walk is provided from the terminal to the parking lot and International Plaza. However, to provide complete separation of pedestrian and vehicular movements throughout Terminal City, would require about 15 such overpasses, each of which would be 200' to 300' in length. As a result, pedestrian overpasses will be used at important crossings but grade crossings will be allowed. Pavement marking and signing will be used to mark the grade crossings initially and electrical conduit space has been provided for future traffic signalization if found desirable. Such a signal system would not unduly delay vehicular traffic, as a progressive sequence could be provided around the loop roadway. Pedestrian controls would be provided to allow them to cross the roadways, but right-of-way would only be given outside of the progressive vehicle band.

Parking Facilities

A variety of parking needs must be provided for Terminal City. Public

short-time and long-time parking and terminal employees must be accommodated. Special parking is required for airport coaches, taxicabs, rented cars, airline business agents, and VIP's.

Fig. 6 shows the typical provision for public short-time and long-time parking and employee parking. Short-time parking is accomplished in the metered parking areas shown in the mall between turnaround roadways. These metered areas are generally provided immediately in front of each terminal building and allow 30 minute parking. To obtain maximum parking, right angle parking was used, but a stall width of 9' and an aisle width of 29' was utilized to insure one-maneuver parking. Note that entrance to the lots is at the far end as approached on the one-way loop roadway. This was done to provide an ample merging and cross-weaving area and to eliminate a direct crossing of traffic entering the metered areas with traffic using the turnaround roadways. Special study was given to the location of parking meters and they were placed 1' inside the driver's side of the parking stall. A special barrier type foundation post was also used, so that the meters could be placed close enough to the edge of the paved area to be reached without stepping from the paved area. Double markings were placed between stalls, so that cars would be guided into the center of the parking spaces.

Public parking lots were located across the mall from the terminals within the terminal roadway loop. Conventional right angle design parking was used with 8-1/2' x 18' spaces and 24' aisles. Aisles are generally at right angle to the terminal buildings. It has been found that this has the advantage of providing more convenient routes for pedestrians and eliminates long, speed encouraging vehicular aisles with dangerous four-way right angle intersections. Curbed islands were provided at each end of the parking rows to control parking and to provide a location for necessary parking lot section number and traffic control signs. Without such islands, we have experienced continuing problems with people parking in the main aisles and with constant replacement of signs.

A new feature in the parking lots is the automatic equipment employed at the entrances. Fig. 7 is a picture of the test installation of this equipment, which is a treadle-operated ticket dispenser. Similar equipment is now in use by others, although in our adaptation only a single vehicle gate is used. The sequence of operation is as follows: approaching the ticket dispenser the vehicle crosses a treadle which causes a single, time-stamped ticket to be extended from the dispenser. A flashing arrow and audible bell draw attention to the ticket dispenser. When the parking patron takes the ticket the parking gate ahead is thereby actuated and allows the vehicle to pass into the lot. A second treadle is crossed and lowers the gate. In all equipment, operating time requirements have been reduced to a minimum and the design of the automatic gate allows it to reverse without completely lowering. Two outstanding advantages result from these automatically controlled entrances: the cost of manning the parking lots is reduced and it is possible to use multiple entrances to more conveniently serve parking patrons. All traffic exiting from the parking lot must use the central exit where automatic equipment will compute the parking charge.

Special attention was given to several features of the parking lots. Storage was provided on entrance and exit, based on our established rate of 240 vehicles per hour per attendant and the expected peak rate of arrival and departure. Peak rates were arrived at by increasing average rates on the basis of Poisson's random arrival theory. The parking aisles next to the main

entrance and exit were dead-ended to avoid congestion at the "T" intersection with the main parking lot aisle. Stand-by entrances were provided into the employee parking lot directly in line with the main entrance-exit. This was done in anticipation of overflow public parking at times of special events at Terminal City. Message blank-out signs were provided at the automatic entrances, so that if an entrance is closed, traffic can be directed to the next entrance.

The typical provision for employee parking is also shown in Fig. 6. The public parking lots are located nearer to the terminals with the employee parking to the rear. Separate entrance and exit are provided for the employee areas, generally located away from the public parking entrances and exits, and connecting more directly to Van Wyck Expressway. Thus, mingling of employee and public parkers is minimized. Control of the use of the employee areas is accomplished by automatic gates operated by special cards. The special cards are used instead of a key or similar device because of the flexibility of control required. Employee parking permits are generally purchased on a monthly basis and the gate control must allow use of several different cards to allow grace periods on the monthly tickets and to admit other parkers.

Fig. 5 shows the roadway system and parking areas in front of the International Arrival Building to indicate provisions for special parking. Approximately 25% of air passengers use taxicabs to and from the airport. Taxis will be allowed to discharge over the full length of the terminal frontage. A six cab taxi stand will be established for loading passengers at the east end of the IAB. This location was selected, so that the traffic officer in front of the terminal could control the number of cabs and so that the need for additional cabs could be readily seen from the taxi storage area in the center mall to the east of this location. Airport coaches are used by about 30% of the air passengers and will also be allowed to unload the full length of the terminal curb. A loading area will be established for airport coaches at the west end of the IAB. Storage of airport coaches will be at a remote area located on 150th Street, and coaches will be called as required, probably through the use of radio. Rental cars will be handled in a similar manner with a few parking spaces convenient to the terminal, but with storage at a remote area. Special parking for business agents of the airlines and VIP's was provided convenient to the IAB and Airline Wing Buildings. Business agent parking was located in the mall as an extension of two of the metered parking areas, and the VIP parking was located off the main entrance to Parking Lot 2, with a separate exit to the loop roadway.

In front of the IAB and Wing Buildings, a 33'-three lane roadway has been provided. A three lane road is strongly recommended for terminal frontages because of the frequent double parking that occurs and would completely block a two lane road. Even if ample curb space exists within a hundred feet of the terminal doors, motorists will frequently double park to discharge their passengers immediately in front of the doors.

Signing

Although the traffic signing at New York International Airport deserves a separate discussion, it is briefly mentioned due to its importance in efficiently directing ground transportation. Three interesting features were incorporated

in the signing provided for Terminal City. These were: 1) The use of color in the directional signs, 2) the use of a progressive technique of signing similar to that employed by Burma Shave and, 3) the coordinated design of light poles and signs so that signs could be light pole mounted with a pleasing architectural result.

The use of color and the progressive technique were employed to provide the best signing we could devise to channel traffic destined to the various terminal buildings. The challenge presented by the new terminal development was to direct vehicular traffic, without confusion, to one of ten terminal buildings. Formerly, it had been necessary to merely direct air passengers to a single passenger terminal where they then, on foot, sought out the individual airline. Four sign colors were selected, one to be used on directional signs pertaining to each of the four parking lot areas of Terminal City. The progressive idea was used to list the many terminal destinations in a manner so that they could be read at highway speeds.

Terminal City presented many new challenges in providing and controlling ground transportation. Our plans for meeting these needs have been outlined to you. It is hoped that we have planned wisely, but it would be folly to say we anticipate no changes. Instead, we are sure that we will be continuously busy at New York International Airport as well as our other airports while air passenger activity doubles by 1965 and quadruples by 1975.

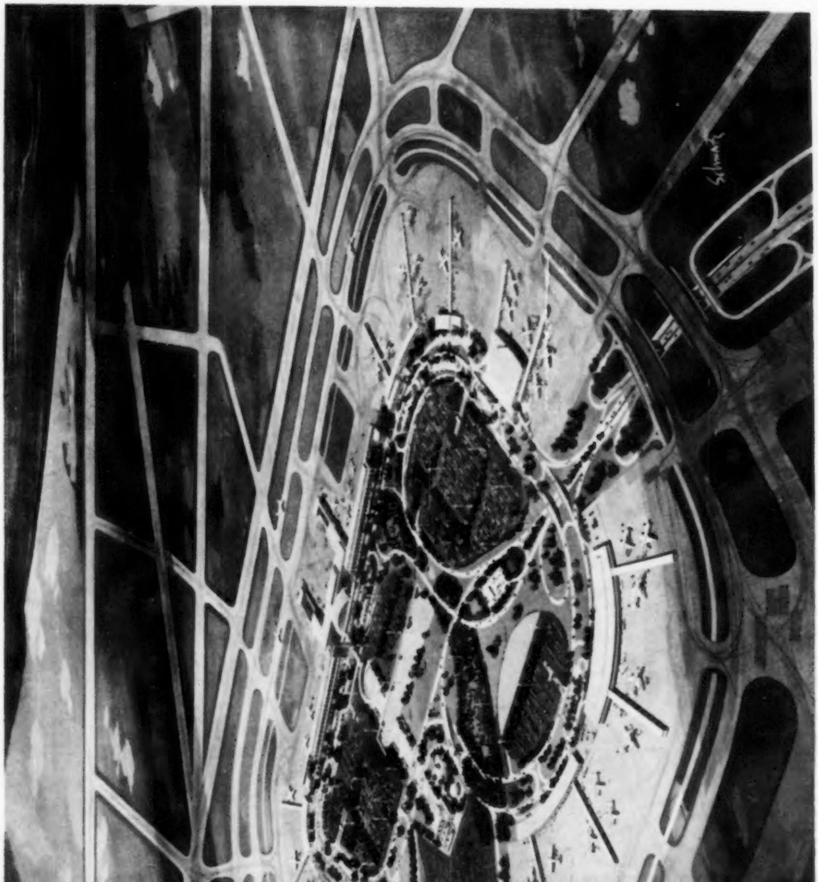

Figure 1 - Artist's Concept of "Terminal City" - New York International Airport

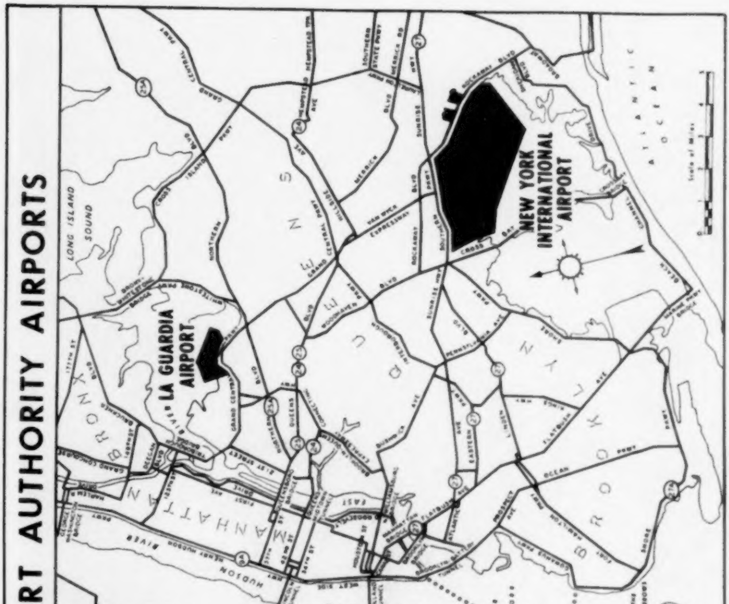

Figure 2 - Northern New Jersey - New York - Regional Airports

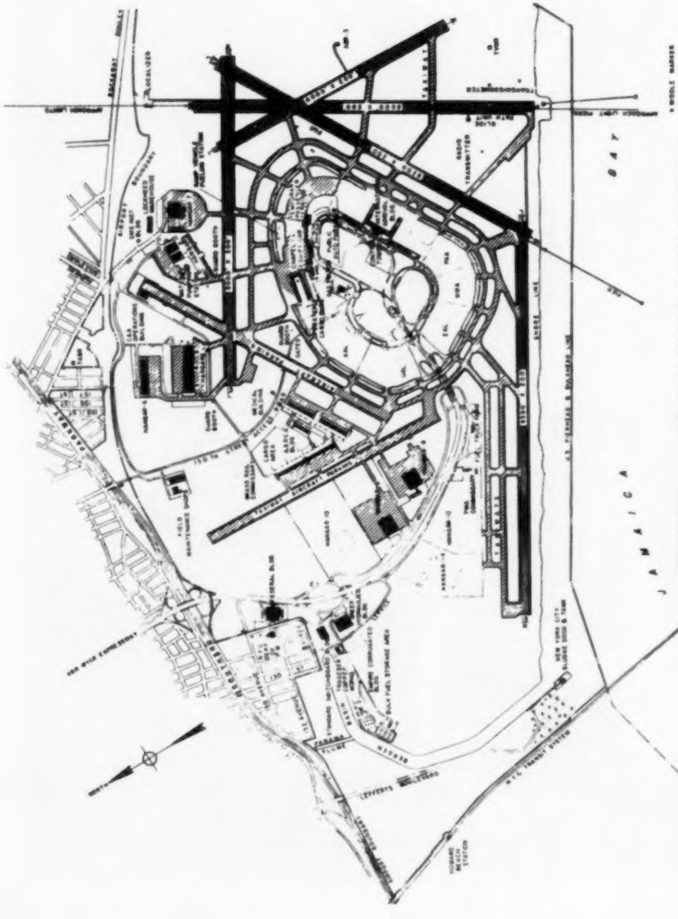

Figure 3 - Maps of New York International Airport

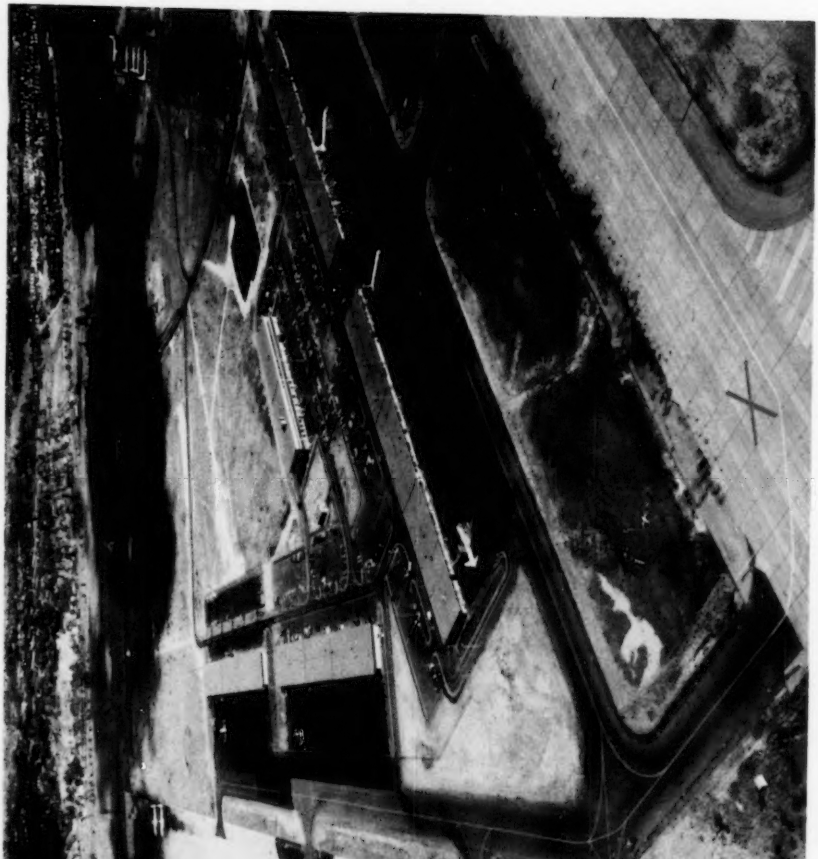

Figure 4 - Air Cargo Buildings - New York International Airport

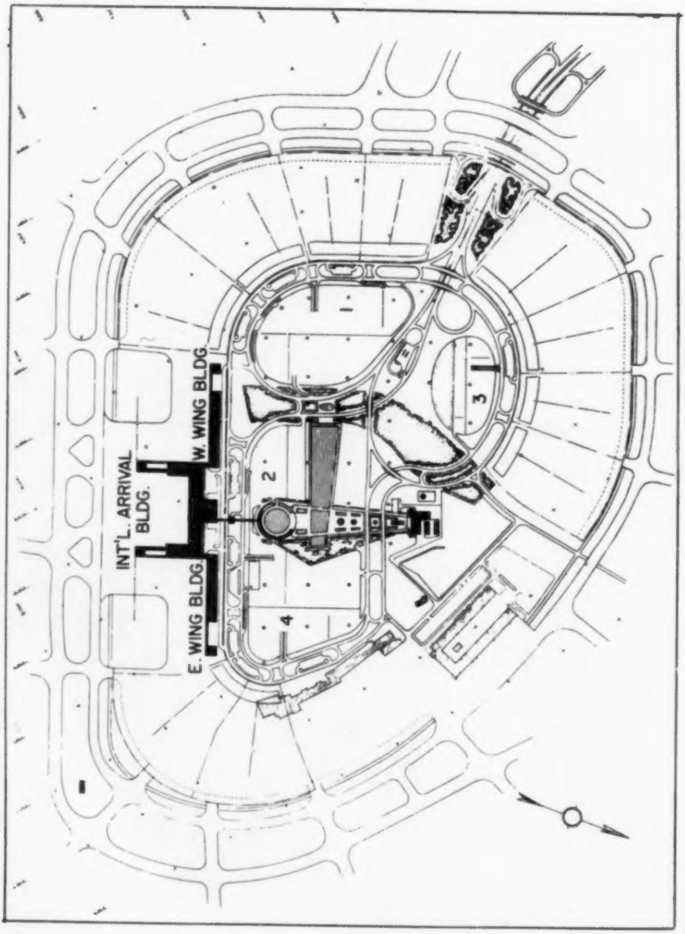

Figure 5 - Map of "Terminal City" - New York International Airport

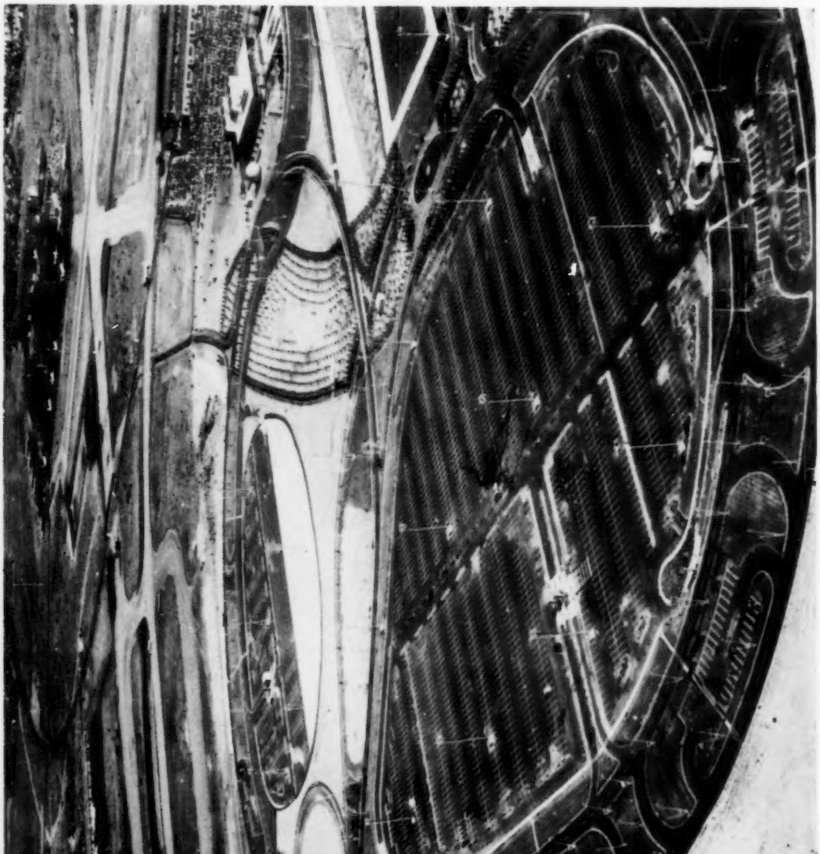

Figure 6 - Aerial Photo of Parking Lot 1 Area - New York International Airport

Figure 7 - Test Installation of Automatic Ticket Dispenser and Gate
New York International Airport

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APPLICATION OF INTERSTATE HIGHWAY DESIGN STANDARDS[a]

J. C. Young,[1] M. ASCE
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SYNOPSIS

Minimum design standards have been set up to govern the design and construction of the Interstate Highway System. These are minimum standards and must be used only as a guide.

In the application of these standards, the highway engineer must use imagination and judgment if the Interstate Highway System is to emerge as something of which everyone will be proud.

INTRODUCTION

The United States is now well started on the most ambitious program of road building ever conceived. The purpose of this gigantic program is to build an integrated network of high standard highways, covering the entire country, which will give the motorist essentially uniform driving conditions regardless of geographical location in which he happens to be travelling.

The enormity of the task of constructing over 40,000 miles of high standard highway has been the subject of many discussions and written papers and is surely recognized by everyone. A less obvious but none-the-less herculean task, is the providing of essentially uniform driving conditions on all parts of the system without creating monotony.

Many miles of high standard highways have been built and are in use today. Consider the many fine turnpikes, which have been built to high standards and which all provide excellent traffic service. Although there are many differences in the design of these facilities, all or nearly all sections of these highways equal or exceed Interstate Standards. The use of Standards as a guide

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1. Chf. Highway Engr., Porter, Urquhart, McCreary and O'Brien, Newark, N. J.

does not necessarily lead to a standardized highway.

This paper will deal with the Standards that have been set up for the Interstate System and the many possible variations in the application of these Standards, particularly as between urban and rural areas.

Standards

Geometric design standards for the National System of Interstate and Defense Highways were drawn up by a Committee of the American Association of State Highway Officials and adopted by that association on July 12, 1956. On July 17, 1956, these Standards were approved by the United States Department of Commerce Bureau of Public Roads.

The Standards as adopted provide, in a few instances, different minimums for urban and rural highways and these are relatively clear cut. Other differences not specifically set forth, will be discussed under other applicable headings.

Control of Access

In urban areas, complete control of access is to be provided.

In rural areas, an exception is made as follows:

Under all of the following conditions, intersections at grade may be permitted in sparsely settled rural areas which are a sufficient distance from municipalities or other traffic-generating areas to be outside their influence, and where no appreciable hazard is created thereby.

(a) The Interstate highway is a 2-lane highway having a DHV (1975) of less than 500.

(b) Each intersection at grade is with a public road or private driveway with little potential for traffic increase and on which the current average daily traffic does not exceed 50 vehicles.

(c) Such intersections do not exceed two per side of the Interstate highway per mile.

(d) Sufficient additional corner right-of-way at each intersection at grade is acquired to insure that access connections on the crossroad are sufficiently removed to minimize interference with the Interstate highway.

(e) The right to eliminate, terminate, or reroute each such public road or private driveway is vested in the appropriate public authority at the time of initial construction.

Although it is clearly the intent of the Standards that full control of access be provided on the entire system, this exception is necessary to prevent overbuilding at the initial stage. Section (e) makes it mandatory that the appropriate public authority have the right to eliminate the intersection at grade when found necessary.

Another exception is quoted as follows:

> "Where a grade separation is called for under these standards and extraordinary conditions exist under which a grade separation would not be in the public interest, an intersection at grade may be permitted through agreement between the State highway department and the Secretary of Commerce."

This exception, although not specifically tied down to either rural or urban conditions, would, no doubt, be confined to rural areas. No set of standards should be so rigid that they make those charged with administration of the standards appear ridiculous. This exception allows reason to prevail when construction of an interchange would be ridiculous.

Design Speed

The design speed of all highways on the system shall be at least 70, 60 and 50 miles per hour for flat, rolling, and mountainous topography, respectively, and depending upon the nature of terrain and development. The design speed in urban areas should be at least 50 miles per hour.

This relaxation in design speed requirements in urban areas, regardless of topography, is obviously to achieve economy in areas of high right-of-way costs. Higher design speeds in urban areas are desirable, however, wherever possible. During peak hours, traffic volumes will generally reduce speeds to a point where 60 or 70 mile designs seem out of line. However, study of accident statistics will show that many and, in some cases, a majority of fatal accidents occur between midnight and 4 A.M. It is during these hours of light traffic that higher design speeds will tend to reduce the more serious types of accident.

Lower design speed does not necessarily mean lower costs. In a recent study of an elevated expressway winding through a metropolitan area, a 40 MPH design speed was submitted based on opinions of the City Administration that no higher speeds were required or desirable through the city. A subsequent re-submittal of a design based on a 50 MPH design speed proved more economical due to shortening of the line which was all on structure with very little additional right-of-way cost. A 60 MPH design speed study proved more costly due to additional parcels of expensive right-of-way required. Careful and comprehensive economic studies of construction and right-of-way costs are needed before adopting the minimum design speed allowed by the Standards.

Medians

Medians in rural areas in flat and rolling topography shall be at least 36 feet wide. Medians in urban and mountainous areas shall be at least 16 feet wide. Narrower medians may be provided in urban areas of high right-of-way cost, on long and costly bridges, and in rugged mountainous terrain, but no median shall be less than 4 feet wide.

The basic difference in median width requirements is the 36 foot minimum in rural areas as against 16 feet required in urban areas. The 36 foot applies only in flat or rolling topography, but a high percentage of the rural interstate system will fall in this category.

With 16 feet as a minimum width in urban areas, a more logical minimum width in rural areas would be 40 feet. It is quite obvious that many areas now rural in character will ultimately develop and become urbanized. With this development is bound to come additional traffic, which in turn will require more lanes on the Interstate system. With the 40 foot minimum median, an additional pair of lanes can be added when required and the resultant 16 foot median will still meet the requirements of the Interstate system in urban areas. It is gratifying to note that several states have realized this fact and are using 40 feet as the absolute minimum in rural areas in flat or rolling topography.

No discussion of median widths would be complete without mention of the variable width median which results from designing each of the two roadways of a divided highway as completely separate highways. This type of design was used to a very great extent on the Garden State Parkway in New Jersey and the New York Thruway. In designing this type of highway, the engineer can take advantage of existing topography to achieve the most economical combination of alignment and grade from the standpoint of grading costs. Also it is frequently possible to use a lesser rate on ascending grades than is used on descending grades. This is highly desirable. This type of design also can eliminate the headlight glare so troublesome on long tangents with minimum medians. This elimination of headlight glare is not automatic however, since the combination of vertical and horizontal alignment of the opposing roadways must be carefully checked to prevent a headlight condition where opposing cars are pointed directly at each other, which would be more hazardous than the case with parallel opposing lanes.

Probably the greatest point in favor of the two separate roadway idea is the fact that it tends to break up the monotony of driving long stretches of highways, particularly where little curvature is involved. Everyone connected with highway engineering or highway safety is aware of the hazard of monotonous driving. The psychologists have been called in and are doing their best to find some method of measuring this "monotony factor". No one knows for sure whether the two separate roadways with their resultant added curvature, decreases the monotony factor and the accidents accompanying it sufficiently to overcome the hazard due to increased curvature. Modern highways that are now in operation, some with separate non-parallel roadways and others of the more conventional parallel roadway type all have excellent safety records. No significant difference is apparent in their safety records. However, more people seem to agree that the separate roadway type of highway is more pleasing to travel, so even though there were no difference in safety records, the comfort and convenience factor would appear to make this type of design somewhat more desirable than the more conventional parallel roadway type.

The narrower medians which are allowable in urban areas of high right-of-way costs, on costly bridges and in rugged mountainous terrain are intended for use only in extreme cases and it appears that at the present time few states are resorting to these narrow medians to any great extent.

Right-of-Way

The Standards wisely do not set up any fixed minimum widths of right-of-way. A statement is made as follows:

> "Fixed minimum widths of right-of-way are not given because wide widths are desirable, conditions may make narrow widths necessary and right-of-way need not be of constant width."

The Standards list minimum desirable widths for rural areas but state that they are to be used as guides. As a matter of fact, the widths given are barely sufficient for the various elements of the cross section and, on most sections of the Interstate highway, right-of-way will be considerably wider than the minimum set up.

For urban areas, no minimum widths are set up even as guides, as the width of right-of-way frequently is a matter of economics and must be tailored to fit conditions at any given location.

Other Standards

Standards are set up covering Traffic Basis, Railroad Crossings, Intersections, Curvature, superelevation and sight distance, Gradients, Width and number of lanes, Shoulders, Slopes, Culverts, Bridges and other structures. Insofar as the Standards themselves are concerned, no differential is made in the Standards for these particular items between rural or urban areas. It is to be noted, however, that the Standards do refer to the American Association of State Highway Officials, "Policy on Geometric Design of Rural Highways" and "Policy on Arterial Highways in Urban Areas," as guides where they are not in conflict with the Standards. These AASHO policies do make some distinction between rural and urban designs for some features, most of which are relatively minor.

The only item in which this difference has any great import are the different design capacities used for rural and urban areas. Although the policies indicate design capacities as high as 1500 vehicles per hour per lane for urban and 1000 cars per hour per lane for rural freeways, somewhat lower figures are actually being used for design purposes on the Interstate system. At first glance, it might seem ridiculous to say that the capacity of an urban freeway is greater than a rural freeway when both facilities may have identical physical characteristics. It appears to be an accepted fact, however, that the travelling public will tolerate a more congested condition if it is of short duration and most urban portions of the Interstate system are only a few miles in length. Driving ten miles through a city on a freeway carrying 1200 to 1500 vehicles per hour per lane is tolerable; whereas a 100 mile trip between cities under these conditions would certainly not be pleasant and is generally conceded to be intolerable from a design standpoint.

Items not Specifically Covered in the Standards

The Interstate Standards are refreshingly brief and concise and by this very briefness they leave a number of decisions up to the judgment of the engineer. This is as it should be, since no set of Standards could ever be compiled which would cover all the multiplicity of conditions which will be encountered in the construction of the Interstate system.

A few of the important items on which the Standards are silent are:

1. Location.
2. Interchange type and spacing.
3. Frontage roads.

These features can be determined only after careful study of all conditions and it is here that the judgment of the engineer will be reflected in the service rendered by the finished product.

Location

The Standards themselves do not state how or where the Interstate system shall be located, nor is it feasible to provide such standards. However, this is the feature and, in most cases, the only feature in which the general public has any great interest. One needs only to listen in on a public hearing concerning the location of a section of the Interstate system to realize just how great this public interest is.

In rural areas, the route location of the Interstate system does not differ greatly from location of a conventional highway. The locater must keep aware of the controlled access feature, but generally speaking, the topographic features will be the major controls. Traffic generating centers along the route tend to bend the line toward them, to provide better traffic service. The final location should be based on a careful balance of total cost versus total traffic service.

In urban areas, the controls are more likely to be man-made than natural. Likewise the cost of right-of-way is frequently the controlling factor rather than construction cost. Also in urban areas, locations must be integrated with local overall master plans. These factors, coupled with the inevitable local pressures, make the location of an urban section of the Interstate system as much a problem of diplomacy as of engineering.

Interchanges

There is probably no subject more controversial among highway engineers than the type and spacing of interchanges, particularly the latter. Oddly enough, although urban freeways present many difficult problems and, in most ways are much more complicated than their rural counterpart, the actual determination of locations for interchanges is far simpler in urban work than in rural areas. Under urban conditions, there is nearly always a network of existing streets, and interchanges even spotted at random will provide fairly good traffic service. In rural areas, however, there is frequently only a very scanty network of local roads and, in some cases, none that are inter-connected, particularly where the Interstate location coincides with an existing highway. This might be used as an argument in favor of locating away from the existing roads. However, this is sometimes neither desirable nor possible. In rural areas, there is seldom a volume of traffic that would warrant construction of interchanges except at very infrequent intervals, probably 20 or 30 miles apart. There are many areas in the Western part of the United States where this is true but there are, nevertheless, cross-roads which will be intercepted which carry a few cars a day. An interchange for this light traffic may seem to be a waste of funds but, in many cases, it is either provide an interchange or construct a long and sometimes costly frontage road which again, is building two roads through an area that may barely need one. Another factor that must be considered, is how far should local traffic be forced to go before being allowed to enter the freeway, even though there is a parallel system of local roads. Every motorist is paying his share of the Interstate system, whether he uses it or not. The Interstate system is not a turnpike.

No one has ever set up any real warrants to determine when an interchange should be built. A method sometimes used is to compute the time saving involved by use of an interchange and the freeway by a certain increment of local traffic, as against the time that would be involved if this same local traffic were forced to use local roads. By using commonly accepted values for time, it is surprising how a small volume of traffic will save the cost of an interchange over a period of say, 20 or 30 years.

Although no conclusions can be drawn as to the proper spacing of interchanges in rural areas, it is of interest to note that practice varies in different sections of the country from a spacing of fifteen or more miles to as little as two miles under somewhat similar conditions.

As previously mentioned, the location of interchanges in urban areas is

less difficult. The actual design may be much more intricate but the location is frequently obvious, due to the local street network and the pattern of traffic desires. The problem is frequently one of trying to get sufficient spacing between ramps to avoid overlap of acceleration and deceleration lanes.

Frontage Roads

Although no standards have been set up for frontage roads, the United States Bureau of Public Roads has published a guide or policy covering this feature. Briefly, there are two warrants for construction of frontage roads:

(a) To restore traffic circulation on the local road system.
(b) To provide access to parcels of land which will be landlocked by construction of the Interstate highway.

The latter is a warrant only if the construction of the frontage road is less costly than buying out the landlocked parcels. Practice throughout the country varies widely, since state laws governing purchase of property differs greatly. There is generally much more use of frontage roads in rural areas than in urban.

CONCLUSION

The standards as now in effect provide a reasonable guide for starting the job. Out of the variations in application of these standards, new and better ideas will surely emerge. The Interstate system should not be allowed to become a hodge-podge of highways with each section reflecting the individual thinking of the engineer responsible for that section; neither should standards be so rigidly adhered to that the system would be monotonously uniform. The challenge to the thousands of engineers who will work on this vast undertaking is to provide a reasonably uniform type of facility and, at the same time, strive to design an interesting highway of which everyone will be proud.

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CONTINUOUS ORIGIN AND DESTINATION TRAFFIC SURVEYS[a]

S. T. Hitchcock[1]
(Proc. Paper 1625)

ABSTRACT

Trip origin and destination data necessary for realistic highway location and design may be outmoded if they do not reflect current economic and transportation conditions. A system of collecting origin and destination information on a continuing basis using a permanent trained interviewing staff and the more exact statistical methods already adopted in continuous traffic counting programs would provide reliable and current information with advantages in technique improvement and possible reduction in costs.

In the relatively brief history of highway traffic planning and research there has been a definite trend toward refinement and improvement of survey procedures to develop more reliable data upon which to base decisions for highway location and design. In evaluating the use of highways and streets within the past 25 years, methods have advanced from simple traffic-volume counts and classification of vehicles by type, to studies of the origin and destination of traffic.

A knowledge of the number of vehicles using a street or highway in a given period of time is not sufficient for planning the location and capacity of future roads and bridges. These counts reveal only the existing volumes and are not necessarily indicative of the route preference of drivers. It is not possible to ascertain where new highway improvements should be located and what their design capacities should be merely by observing traffic flow at selected locations. Only through a comprehensive knowledge of existing trip origins and destinations can the proper location and adequacy of proposed facilities best be determined.

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a. Presented at the Annual Convention of the American Society of Civil Engineers in New York, N. Y., October 16, 1957.

1. Chf., Div. of Highway Transport Research, Bureau of Public Roads, U. S. Dept. of Commerce, Washington, D. C.

Origin and destination (O-D) surveys were first used in connection with specific problems at river crossings and later in the investigation of proposed bypasses around cities. During the late 1940's an increasingly important segment of the progress in O-D techniques and their application was concerned with travel habits in and around urban areas. The mere counting of such urban traffic was not sufficient to determine the desired line of travel since drivers are not restricted to a specific route but may shift from one to another to avoid congestion, delay, poor alinement, and rough streets.

Trips in urban areas may be generated and lie entirely within the area, or they may have either the origin or destination within the area, or they may be passing through and have neither origin or destination in the area. The most frequently used method of obtaining O and D data is by interviewing the residents living in a sample of dwelling units within the urban area. This is usually designed to depict the travel habits on a typical weekday, but may also include weekends and holidays if desired.

Travel information about traffic entering or leaving the city is usually obtained by stopping vehicles on the highway at selected locations on a cordon around the area and interviewing drivers briefly as to the trip they are making on the particular day. This too is done on a sampling basis. By summarizing the information obtained from these two methods, it is possible not only to approximate the travel patterns and volumes on the existing street systems, but what is more important, it is possible to estimate volumes on a desire-line pattern without regard to the layout of existing streets. These surveys are based on the assumption that the day-to-day variations of travel habits including origins and destinations are relatively insignificant.

Such studies give an immediate answer to problems of route planning confronting highway and traffic engineers, but population and its distribution and the economy of the area do not remain static and within a relatively brief period of time the problem is again dominant. Census statistics indicate the changing residential characteristics of our population, decreasing farm population, and increasing suburbanization, but in many cities the decennial census period is too long to use for effective control of highway route planning.

In an effort to keep up to date with respect to an area's requirements, serious consideration needs to be given not only to making a study of the origin and destination of travel on which to base the area's highway plan, but also to keeping it current to changing population and economic requirements. There is not at the present time any experience in continuous interviewing for obtaining highway travel data on a repetitive schedule that is indicative of results that might be expected. In an effort to explore the feasibility of doing this very thing, preliminary studies have recently been completed in the New York area for that part of the problem involving traffic entering or leaving the urban area.

Traffic surveys involving sampling procedures are designed to measure segments of the repetitive travel patterns that are characteristic of group human behavior. On this basis, therefore, it is possible to make broader generalizations from limited observations through the application of sampling theory. Several fundamental traffic flow patterns or fluctuations have been recognized. Traffic volumes vary by hours of the day, from day to day, and from month to month; but the hourly fluctuations repeat themselves from day to day, the daily variations are relatively insignificant on weekdays, the variation between successive weeks is not appreciable, the monthly fluctuations generally repeat themselves from year to year, and in urban areas these fluctuations are relatively small.

Traffic counts are usually made to develop estimates of the annual average number of vehicles on a section of road each day and the peak hourly volumes which serve as design criteria. The existence of these traffic patterns has permitted comprehensive studies of the annual average daily traffic (ADT) based largely upon data from sample counts usually taken only once a year for a duration of 24 or 48 hours. These short counts are then expanded and adjusted to reflect periodic variations as determined from continuous counts at representative permanent stations and from periodic counts at strategically located control stations.

Through years of research and investigation in the traffic-counting field, the existence of regular patterns of variation and fluctuation over various periods of time have been established, verified, and utilized. Development thus far in the realm of origin-to-destination travel has been based on the assumption that similar patterns exist in travel habits as in volume characteristics. It is now time to appraise the reliability of O-D surveys involving only one interview period at a particular station; i.e., are there significant variations in origins and destinations on a day-to-day (weekday) basis, or by weeks, months, or seasons? If the relationships between various time patterns in O and D movements are to be determined with a reasonable degree of accuracy, it might be advantageous to organize field procedures for interviewing on a continuous basis, conducting the survey over an extended period of time instead of a one-time survey.

The major reason for considering the use of the continuous-type survey, whereby a sample of the traffic is interviewed for O and D of travel throughout a preselected period of time (month, season, or year), is to evaluate those variations not accounted for in previous surveys.

The data provided by a year or two of continuous O and D survey operations will be extremely useful. It will then be possible to investigate the actual periodic variability of O-D volumes and the statistical reliability of measures of difference between various interviewing methods. This research could also be associated with statistical studies of traffic volume and classification counts which have a much longer history.

There are other advantages to be gained from the continuous-survey technique. Most obvious is that it affords continuous, up-to-date information for developing the trend analyses that are so necessary in forecasting future traffic patterns. These forecasts form the basis for the planning and design of the highway facilities of tomorrow.

Also, unlike the large labor supply demanded by the one-time survey on a temporary basis, a continuous approach levels the workload and enables the development of a small, coherent, well-trained group of interviewers, who may be employed on a permanent basis. This should mean the collection of more accurate information and elimination of many personnel problems.

Engineers and others in the traffic and transportation field have been aware of many of these advantages for some time, but the general feeling has been that the difficulties outweighed the advantages. Consider for a moment some of the physical problems that will be encountered and must be solved when O and D interviews are taken continuously. Perhaps the most frequently mentioned handicap is the added likelihood of evasion of the interview lanes or roads by drivers who are "in a hurry." This practice could cause a serious bias in the O-D patterns observed. Another problem is how to handle the interviewing during peak hours when the traffic loads might cause excessive back-ups. The best answers to this are probably linked with the method of

sample selection. Of course, an added burden is the greatly increased number of continuous traffic counts that will be required to provide estimates for sample design purposes and to expand sample interview results.

Some of these problems are less formidable on certain facilities than on others. On the one hand, bridge, tunnel, and highway toll facilities are especially adapted to the continuous survey. For instance, permanent automatic traffic volume and classification counts are normally available with no increased effort, as a by-product of the required toll collection operation. The stopping of selected vehicles is a minor problem since all traffic must stop to pay the toll. If unreasonable back-ups are to be avoided, however, the O and D survey questionnaire will have to be limited essentially to the two basic questions; Where did this trip begin? Where will this trip end? At most, an interviewer at a toll facility might also ask the purpose of trip.

On the other hand, the application of the continuous-survey technique presents major hurdles with respect to toll-free facilities. For two-lane highways, road blocks must be set up similar to those required for the one-time survey method. On multilane roads, it will not be feasible to stop all traffic on a continuous basis. Nevertheless, selection of a representative sample requires that drivers in all lanes be interviewed at one time or another. Therefore, thought must be given to the practicability of channeling traffic into a single lane or perhaps adding an additional lane for interviewing vehicles withdrawn as a sample from any and all operational lanes at the station location. In any case, need for the utmost cooperation from highway patrol or other enforcement officers is obvious in order to maintain efficient and safe traffic control.

In addition to the physical problems involved there are also several questions of a theoretical nature. In broad terms, the major question concerns sample design. For example, should it be simple random sample, or a systematic sample; should it be stratified; and should a uniform or variable sampling rate be applied? Involved here are such items as number of lanes and working-hour shifts, vehicle volumes, direction of traffic, and periodic variations. Even with respect to seasons of the year, research in traffic counts indicates that seasonal traffic variations may not accompany the solar seasons. In the O-D field there is no measure of monthly or daily variations. Neither are there measures of the accuracy of data collected under the interviewing conditions now in use or anticipated. A certain amount of information will have to be assembled before these questions can be answered. The accuracy of various methods must be measured and compared and then these facts should be related to the costs of the respective procedures so that the efficiency of the sample can be accurately determined. These relationships can only be approximated at this time.

Eventually the only primary question will be what tolerance in the estimate can be accepted by the highway administrator or design engineer in his need for data on which to make decisions or prepare designs for new facilities or improvements. Once this is determined a sample size and schedule of interviewing operations can be programed within those limits.

In view of the relative ease of conducting a continuous sample survey at toll facilities for obtaining O and D information, The Port of New York Authority is considering this method. For the past two decades, they have been conducting periodic, one-time type, O-D surveys, recently at 3-year intervals. Their latest survey of this type was carried out last fall and provided data concerning trips over the facilities operated by the Port Authority crossing

the Hudson River and the bridges linking Staten Island with New Jersey.

Several other cooperating agencies participated in this extensive survey covering the entire New York metropolitan region. In addition to the Port Authority facilities, interviews also were taken at stations along the Westchester County-New York City (Bronx) boundary line and at the Tappan Zee Bridge by the State of New York Department of Public Works, and at the free bridges crossing the East River by the City of New York's Department of Traffic and all toll facilities of the Triborough Bridge and Tunnel Authority.

Interviews were taken at each facility on a Wednesday, an "average" weekday, a Saturday, and a Sunday of October, 1956, considered an "average" month. At that time, the Bureau of Public Roads cooperated with the Port Authority in suggesting the theoretical number of sample cases, which over a full season of a continuous survey might produce results with a given reliability comparable to the one-time study. A sample approximating the suggested size was then selected as a systematic subsample of the larger one-time sample taken on the Hudson River crossings during the three days of the survey. The subsample varied from every third to every fourth vehicle selected in the over-all sample, depending upon the specific bridge or tunnel. To test the possibility of improving efficiency, some analyses have been made relating the subsample to the more extensive sample. First the larger sample was expanded and a table prepared representing the total daily zone-to-zone vehicular movements, which cross over the George Washington Bridge and through the Holland or Lincoln Tunnels on each of the three days. There were some 250 combinations of these zonal movements between the 32 zones, varying from zero to over 8,300 trips per day. Next the subsample, already expanded according to its weight in the over-all sample, was expanded further on the basis of each day's total at each facility to represent a full day's travel. Thus expanded, a zone-to-zone tabulation was prepared similar to the first and these were compared cell by cell. In order to apply statistical measures to this comparative analysis, the cells were grouped into 10 trip-volume categories for each of the three trans-Hudson facilities on each of the three days separately. Then for each volume group the differences between the two expanded samples were calculated and expressed as a percentage of the larger sample. Finally, for each facility-day, the standard deviation of the percentage difference was computed from the true mean of the percentage differences of each volume group.

When plotted against traffic volume these standard deviations produced curves which were characteristic of normally distributed data and were similar to those in Figs. 1 and 2. Fig. 1 shows the standard deviation of the percentage differences between the sample and subsample estimates of the number of trips between origin and destination zones by various traffic volume groups on a weekday for the George Washington Bridge, the Lincoln Tunnel, and the Holland Tunnel. Fig. 2 shows similar standard deviation for the George Washington Bridge on a weekday, a Saturday, and a Sunday. The similarity of the patterns on these two charts is notable and similar patterns were found for the other days at these facilities. For all cases studied the standard deviations varied from about 140 per cent in the very small volume groups to less than 10 per cent when the trip volumes were over 1,000 per day. The standard deviation usually was less than 40 per cent for interzone volumes over 100 trips per day and under 25 per cent for trips in the 300 to 500 volume group and greater. The practical significance of these standard deviations means that approximately two-thirds of the percentage differences are

included in the range bounded by the mean plus or minus one standard deviation. In general, the mean value will be close to zero.

Assuming that the variations within the strata of days (Wednesday, Saturday, and Sunday) is not of great importance, this analysis shows that the selected subsample size gives reliable estimates of trips between origin and destination in the range of large interzonal movements. On an annual basis, it will provide satisfactory results for small volumes and much better results for large volumes. It may be that the smaller sample alone would more efficiently have given results of sufficient reliability in the high volume ranges to meet the needs of the particular survey.

However, this analysis still lacks any measure of the periodic (hourly, daily, monthly, etc.) variation of the origin and destination data and therefore it is not a true test of the relative reliability of anticipated continuous samples versus the one-time survey. For this it is necessary to have data from actual continuous sampling operations over an extended period of time.

The Port of New York Authority plans to initiate this fall a continuous sampling program to determine origins and destinations of vehicular trips across the Hudson River and to and from Staten Island. After considering several possibilities they will test a sampling plan prepared by Dr. Leslie Kish of the University of Michigan's Survey Research Center. The workability of this plan under field conditions and unforeseen circumstances will indicate whether any modifications will be necessary. For the present it will be sufficient to say that an estimated 135,000 interviews will be obtained during the course of the first year's field work. The standard error of estimate for a subclass of the sample that is one per cent of the total (1,350 schedules) is expected to range between 0.03 and 0.06 per cent. Assuming that the standard error of estimate will be about 0.05 per cent, a complete count over the year instead of a sample would result in a value for the one per cent subclass that would fall within the range bounded by one per cent plus or minus 0.1 per cent. If many similar samples were drawn, similarly derived statements would be right about 95 times out of 100. This is considered to be a good statistical ratio for a reasonable and economically designed sample. A sample of 135,000 vehicle-trips out of an estimated 90 million crossing the Port of New York Authority facilities next year (1958) therefore implies an over-all annual sampling rate of 1 out of 650.

The schedule for obtaining this sample takes into consideration time, location and volume of traffic by a systematic sampling of days and hour periods at specific facilities, weighted by the estimated average hourly traffic. In this way every "nth" vehicle can then be selected for interviewing in each specified traffic lane so that an over-all rate of 1 in 650 is obtained.

This first attempt for continuous sampling may best be characterized by the uniform sampling rate. This may not prove to be the most practical approach and it does not preclude the possibility of using alternate procedures. Another design suggested by the Bureau of Public Roads last year was predicated upon a differential sampling rate depending upon the particular facility under observation. This procedure would guarantee a stated reliability for each independent facility rather than for all facilities combined. Still other methods and combinations or modifications of these are feasible. Determination of the most desirable techniques must await the outcome of initial experiences and solution of the problems remaining to be solved.

SUMMARY

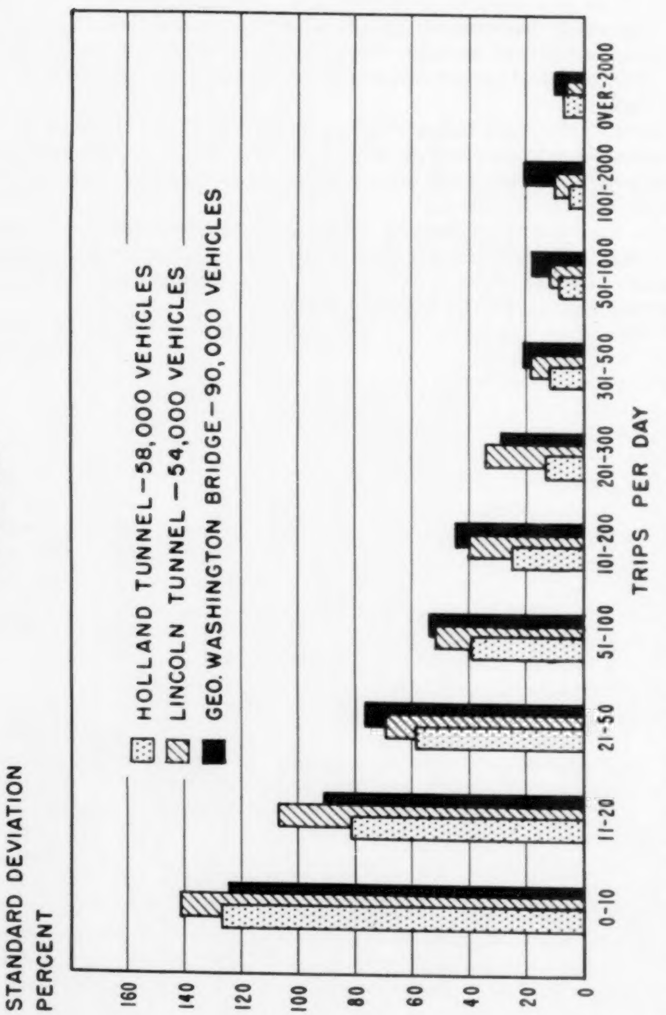
In summary, trip origin and destination data are necessary for the most realistic location and design of highway facilities. The results of the one-time survey procedures for obtaining these data may be outmoded as they have not kept pace with economic and transportation changes. A system of collecting origin and destination information on a continuing basis using the more exact statistical methods being employed in traffic-counting programs and a better trained interviewing staff would provide more reliable, up-to-date information.

In spite of the many and serious problems which are associated with a continuous-sampling survey, particularly with respect to operations on toll-free highways, it appears to offer advantages in technique improvement and possible reduction in costs.

To be successful, the driving public must be convinced that the studies are being conducted to determine where traffic is going, what improvements are necessary and that they can be successfully developed only if each driver co-operates by taking time to answer the questions asked.

STANDARD DEVIATION OF SUB-SAMPLE FROM SAMPLE ESTIMATES OF TRIPS BETWEEN O-D ZONES

WEEKDAY

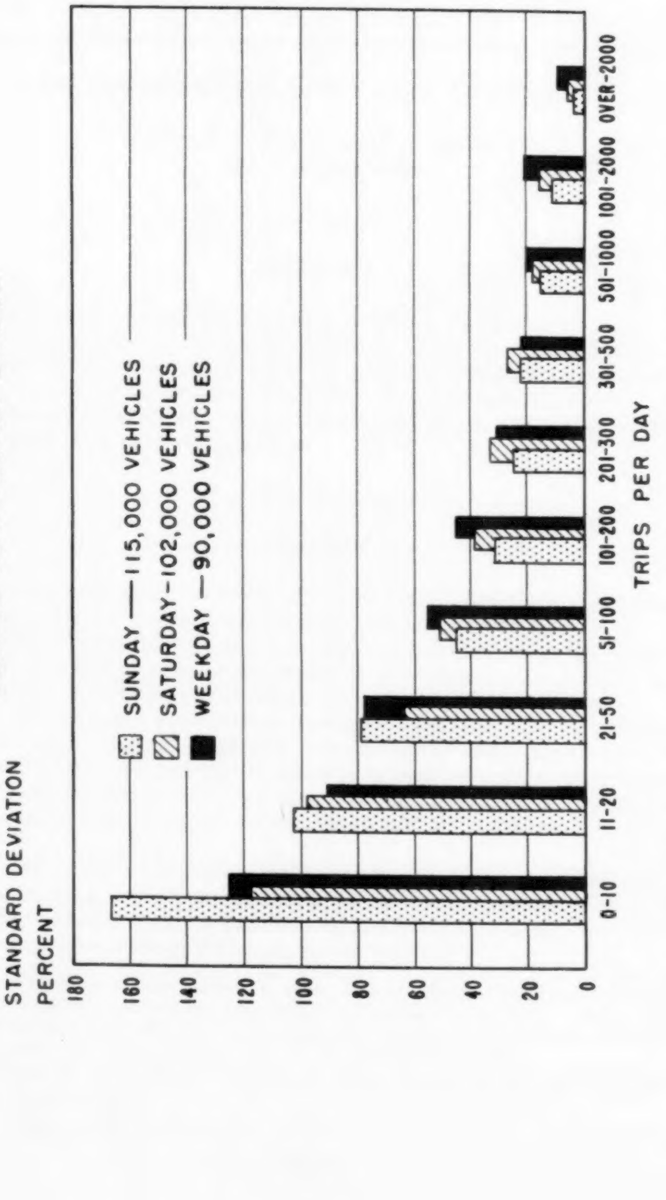


SOURCE: THE PORT OF NEW YORK AUTHORITY O AND D TRAFFIC SURVEY—OCT. 1956

FIGURE – 1

STANDARD DEVIATION OF SUB-SAMPLE FROM SAMPLE ESTIMATES OF TRIPS BETWEEN O-D ZONES

GEORGE WASHINGTON BRIDGE



SOURCE: THE PORT OF NEW YORK AUTHORITY O AND D. TRAFFIC SURVEY-OCT. 1956

FIGURE-2

Paper 1626 May, 1958 HW 2

Journal of the
HIGHWAY DIVISION
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QUALITY CONTROL FOR LARGE HIGHWAY PROJECTS[a]

Edward A. Abdun-Nur,[1] M. ASCE
(Proc. Paper 1626)

ABSTRACT

A discussion of a broadened approach to quality control dictated by factors inherent in large-scale accelerated programs. This stresses application of control not only to materials, but also to construction operations and procedures. The basic factors are specifically designed specifications, a continuous training program for inspectors and engineers, and management that is in syn ,athy with such an approach.

SYNOPSIS

The development of toll highway work has called attention to problems to be faced by builders of other large highway projects. The similarity between toll highways and other large highway projects arises from accelerated schedules, high design standards, construction during winter months, increased costs, and shortages of materials and technical personnel.

These factors place emphasis on a concept of quality control, which stresses that control is not only a problem concerning the materials that are incorporated in the work, but that it needs to be applied equally as well to construction methods and operations. Lessons can be learned from industry, which has faced similar problems and which has developed reasonable solutions.

Three basic tenets for such control are proposed: setting up standards of quality, developing specifications that permit the attainment of these standards, and organizing and training a supervisory and inspection force to convert the written provisions of the specifications into REALITY.

Note: Discussion open until October 1, 1958. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 1626 is part of the copyrighted Journal of the Highway Division, Proceedings of the American Society of Civil Engineers, Vol. 84, No. HW 1, May, 1958.

a. Presented at the Buffalo Convention of the American Society of Civil Engineers, June, 1957.

1. Cons. Engr., Denver, Colo.

Reporting as part of the functions of inspection, and the importance of reports as records to help in case of claims, lawsuits, and later difficulties is stressed.

To carry out such a program requires engineering supervisors of broad outlook, sympathetic towards this approach, who can achieve a balance among speed, quality and cost, and who can deal fairly and realistically with the problems as they arise, thus converting plans and specifications into the REALITY of the finished highway, with the utmost efficiency, economy, and speed. Above all, it requires the wholehearted support and backing of management.

It is concluded that this approach to quality control lowers costs, improves quality, speed operations, and provides a highway which will require minimum maintenance and will give utmost uninterrupted use.

INTRODUCTION

In the past twenty years, toll highways have developed from toddling infants to full maturity. Much has been learned during this development about the problems that accompany the construction of large highway projects. Out of these problems has emerged a new concept of quality control—a concept born of many factors, the most significant of which are:

1. Accelerated construction programs
2. High design standards
3. Necessity for winter work
4. Simultaneous operation of large number of contractors on a single large project
5. Rising costs of labor and materials
6. Shortage of materials
7. Shortage of qualified technical personnel

To cope with these factors and still maintain quality, lower costs, increase the useful life of the facility or structure, reduce maintenance, and provide more uninterrupted use and comfort to the motoring public, requires a much broader and more comprehensive concept of quality control than has been considered necessary on work of this type.

Quality control, as visualized here, consists in the establishment of the proper level of quality for a given engineering project, and controlling and conducting operations in a manner that will insure that the required level of quality is attained and maintained. Thus, it involves not only the control of materials, but also the manner in which materials are used in the work. Its most important factor is UNIFORMITY, which is the tool for attaining the quality desired effectively and efficiently.

Its basic principles are automation and "self-functioning" features. These principles have proved themselves by reducing the variable and indeterminate human factor, reducing labor and inspection which are usually the most expensive items, and minimizing waste of materials and of finished products which would otherwise fail to meet requirements. To these basic principles can be added end-product provisions which permit the contractor to utilize his ingenuity, and statistical treatment of data which detects significant variations. With this combination, one has the basis for obtaining control and for measuring its results.

To set up this progressive type of quality control requires the following:

1. Determine the level of quality and degree of uniformity needed
2. Design specifications that will permit obtaining results of the desired quality
3. Organize and train an inspection force and engineering supervision that is capable of taking the words of the specifications and the lines of the drawings and turning them into the REALITY of the finished highway.

If any one of these three elements is neglected, proper quality control can not be attained and the results will be higher costs, premature failures, and increased maintenance.

This paper presents some principles which the author has used in applying the foregoing approach to quality control. It is hoped that these may prove equally useful to others faced with similar situations, and that the principles described will encourage the use of this broadened and progressive approach to quality control.

Determining the level of quality and degree of uniformity needed involves a combination of policy, finance, proposed use of the highway, expected life of the facility, design standards and requirements, availability of materials, and general trends and practices in the area. This phase of quality control will not be examined in detail in this discussion. The reader is cautioned, however, that it is most important and should receive very careful consideration, particularly by management, as once it is established, it should be adhered to. Any level of quality control starts with the top executive, and no level can be maintained without the continuous support of management.

Designing adequate and realistic specifications will be discussed in some detail, as it applies in general to various materials and methods of construction.

Organizing an inspection force, the basic tenets and principles involve, some of the problems encountered in multi-contract project, and requirements of engineering supervision for this type of quality control will also be explored.

Design of Specifications

The basic solution outlined above requires the designing of specifications that will permit the attainment of the quality desired for the project. No structural designer would take a given design and use it for all similar structures irrespective of location, service requirement, and local conditions. In the same manner, no single set of specifications can be applied successfully to all phases of a large number of widely scattered highway projects.

Similarly, each project and location presents different problems of inspection and engineering supervision that must be coordinated with the specification requirements to obtain the quality control desired.

Specifications must therefore remain dynamic and be adapted to each job situation and quality level desired. Like designs, they can make or break a project, increase or decrease costs, delay or expedite progress of the work, affect claims, and motivate contractors to cooperate.

To develop such specifications requires creative engineers of the highest caliber with broad experience and full realization of the problems involved in:

1. Design
2. Materials
3. Specifications
4. Contracts
5. Construction
6. Control and inspection, and with a
7. Progressive philosophy of engineering

Such men must be willing to make use of creative ideas, be able to think through a problem from design to construction, and have the strength of their convictions and be willing to defend them. Consultants who are unfettered by organizational procedures and departmentalization can contribute a well-rounded and fresh viewpoint.

How, then, does one go about designing such specifications?

Ideas borrowed from the structural designer provide a good start, and it is logical to begin with a set of "design criteria" for the specifications, set up individually for the job on hand. The following discussion indicates how the author developed "design criteria" for the Standard Specifications of a large toll highway. Each criterion is followed by examples of the provisions in which it was applied:

Choose Quality Desired and Be Willing to Pay for It

This does not mean that one should pay any price, no matter how high. The basic philosphy is to decide on quality desired and then when the specifications' provisions have been set up to assure the attainment of this quality, lowest price through competitive bids can be accepted. It does not make any difference whether the provision is concerned with steel, cement, paint, or earthwork—this principle can be applied effectively. The reverse—determining quality from a price that has been set because someone thinks that is all that should be paid—cannot be tolerated in good engineering and will invariably result in trouble.

Require as Much Uniformity as Practicable

Within a given level of quality the more uniformity that is attained, the better the work. This is a fundamental principle in quality control. It applies to construction operations and procedures as well as to materials and supplies. It is obtained by applying criteria similar to those enumerated below. In general, a contractor will find that increased uniformity will in itself reduce costs because of the continuous orderliness achieved thereby, and because the careful study required to attain uniformity will permit the elimination of many of the inefficient operations.

Use "Self-Functioning" Features

This is perhaps the most fundamental of the criteria. It implies that a feature functions with minimum of attention and does away with a great deal of the variable and unreliable human element. This permits control in spite of accelerated schedules and unpleasant winter or summer weather, because of the minimal use of the human factor. "Self-functioning" features can be applied to nearly every operation, and it is amazing how rewarding one finds the effort spent on this phase of the work. Here are a few examples:

a. Permit the contractor to chose his source within a class of materials, but hold him to that source after he has made his decision. This narrows the variation to a single source. The principle can be applied to borrow, base course material, aggregate, cement, asphalt, paint, and most other items in the specifications.

b. Use lump sum items whenever possible. This reduces the cost of engineering supervision, and releases technical personnel who would otherwise be occupied in making unit measurements, to other more important tasks. Clearing and grubbing is a very worthwhile application of this principle. The principle can often be applied to earthwork, to small structures such as inlets, to manholes of approximately the same size, to catch-basins, and to a myriad of little items that cost more to measure than they are worth.

c. Finish roll earthwork or base courses with 2 to 4 coverages of a 50 ton "super-compactor." This will cover every square foot, and will detect poorly compacted areas that have been missed by the density tests.

d. Finish screen coarse aggregates, for concrete, over the batching bins, for the following advantages:

  (1) Minimizes segregation by giving the aggregate one final shuffling in the last handling, immediately before use—increasing uniformity.
  (2) Makes separation between sizes more definite—again increasing uniformity.
  (3) Rids the mass of aggregate of the fine undersize which develops as a result of degradation. This fine undersize introduces large variations from batch to batch. By eliminating it, uniformity is further enhanced.
  (4) By disclosing excessive amounts of rejects, acts as a "self-functioning" control which keeps the producer alert.
  (5) Lowers costs by eliminating expensive and restrictive stockpiling requirements and by reducing inspection.
  (6) Reduces the number of cranes and operators for a given job, and replaces these with less expensive conveyors and screens which need only occasional maintenance.

e. Increase uniformity by installing electric moisture meters in fine aggregate weigh hoppers, to provide quick information for adjusting batch weights, to take into account variations in sand moisture.

f. Include a maximum allowable concrete temperature in summer weather. This is "self-functioning" in that it reduces the intensity of hot weather concreting problems, facilitates finishing operations, improves strength and quality, and reduces plastic shrinkage cracking.

g. Use water reducing retarders in portland cement concrete, that help uniformity by permitting a uniform water and cement content to be maintained in spite of changes in temperature between summer and winter.

h. Use insulation in cold weather concreting in lieu of artificial heat. This permits heat of hydration to keep the concrete from freezing, and reduces dependence on the human element to maintain artificial heat. The danger in setting fire to forms and damaging the concrete is eliminated.

i. Cure concrete by using pigmented curing compound, which when once applied to the concrete surface requires no maintenance labor, and is

easily inspected for damage that may occur from careless construction operations.

j. Use automatic concrete batch plants and bituminous plants, with interlocking of the various operations, and with automatic recorders. Once set for a given operation, these become "self-functioning," provide a permanent record of what transpired, and improve uniformity over even the best that can be attained by manual operations.

Specify Automatic Features

Use mechanization as much as possible and the automatic type features where possible. These again improve operations by reducing reliance on the undependable human element. In the long run, they reduce labor and costs as has been found in industrial operations, railroads, and wherever automatic equipment has replaced the human element. Many of the mechanization and automation features overlap with the "self-functioning" features, but the most important ones warrant a brief listing:

a. Automatic electric meters in sand weigh hoppers for concrete
b. Finish screening of coarse aggregate for concrete
c. Automatic dispensing equipment for admixtures for concrete
d. Mechanical application of concrete curing compound
e. Interlocks, recorders, and automatic operation of batch plants and mix plants for portland cement concrete and for bituminous plants
f. Traveling mixing equipment that mixes uniformly the proper amount of water in the soil and leaves the layer behind it ready for compaction

Write-In Motivations for Uniformity

This criterion uses the profit motive as an incentive for the contractor to cooperate in producing increased uniformity. One of the best examples is to base the required strength of concrete on the degree of uniformity obtained. As uniformity increases, the average required strength decreases, and therefore, other things being equal, the cement required is lowered, thus increasing profits.

Provide Penalties for Lack of Uniformity

This is the reverse of the item above and again is most easily illustrated by assuming lack of uniformity which would require higher average concrete strengths, and therefore a higher cement content, with correspondingly increased cost.

Use End-Product Provisions

Encouraging contractors to use ingenuity by including end-product provisions often results in improved methods and added profits to the contractor. Sometimes, this may be useful in obtaining the desired methods without restrictive requirements. Allowing increased thickness of granular materials in earthwork, as long as the contractor can attain the required density, will prompt him to find equipment that will permit him to do it.

Include by Reference Standards and Standard Specifications

Ready standards formulated by such organizations as AASHO, ASTM, AC 1,

and others should be included by reference. At times, it may be necessary to modify some of their provisions, but in any case, this reduces the details in the general specifications being prepared, and provides standards developed by specialized groups jointly representing consumers, producers, and general interest factions.

Investigate Local Conditions and Problems

Specifications written for hot, dry Arizona are not necessarily applicable to cold, wet Illinois. Such items as climate, exposure, weather, availability of materials, equipment, and other items may make provisions which are adequately suited for a given purpose in a given locality, entirely unsatisfactory for the same purpose in another geographical area. It is therefore most important to study the local problems and develop the facts and data needed to provide the engineer with specification provisions that will permit doing the work properly and adequately in a given locale.

Use Statistical Methods Wherever Possible

This replaces guesswork with statistical averages and probabilities. It can be applied to the control of portland cement concrete strengths, the stability and flow of bituminous concrete mixtures, the compaction of soils, the variations in gradation of aggregates, and to many other operations. No one can work 100% of the time to a rigid line of demarcation, and therefore from a practical standpoint, sharp limits without leeway cannot be enforced. The statistical approach takes this into consideration, and permits the application of a calculated risk that will not endanger the structure, yet can provide a realistic range within which the contractor can operate in a practical manner.

In concrete, for example, 20% of the tests may be allowed to fall below a prescribed limit. Some "lows" are there anyway whether allowed or not. This is therefore a realistic approach and does not weaken a structure, inasmuch as:

a. Concrete in a structure usually develops a higher ultimate strength than that indicated by standard cured test cylinders.
b. A concrete batch usually gets mixed with other batches during placing operations and therefore there is a certain averaging effect.
c. Surrounding concrete supports and confines any one part of a structure that may be slightly weaker than the rest of it.
d. The factors of safety used in design permit a certain degree of tolerance.

Similar provisions can be developed for other materials.

Permit Flexibility as Long as Uniformity is Maintained

This permits the contractor a choice of materials and operations that will not adversely affect the project.

Keep Restrictions to a Minimum

Restrict the specifications only when it is needed to improve or facilitate the work. Otherwise restrictive provisions increase costs unnecessarily.

Avoid the Use of Brand Names or "Or Equal"

A study of what is really needed for a special situation or to solve a problem, will usually permit the engineer to determine the basic requirements and thus avoid specifying brand names, which give a decided advantage to the product named. Every time a brand name or "or equal" is used, costs increase, as the contractor is either bidding on a restricted product or is counting on the unknown whims of the engineer to decide what can be considered "equal."

Reduce to a Minimum Phrases such as "as Determined by the Engineer"

It is realized that such phrases cannot be entirely eliminated, yet their unnecessary use forces the contractor to bid on the engineer's whims and, therefore increases costs, as the contractor has to pad his prices to protect himself.

Keep Requirements High

When absolute need arises, one can relax requirements, but it raises costs to upgrade weak specifications, as the owner then loses the advantage of competitive bidding and is at a disadvantage in negotiating a price. A position of strength (high requirements) gives an advantageous bargaining power when negotiating needed changes.

These design criteria for developing realistic specifications have been used in the past in different combinations on a variety of projects, and therefore are "job tested." They assure increased uniformity and therefore a higher quality. Others will occur to the engineer who tries this approach in developing specifications.

Inspection

Inspection is as important a factor in quality control as are specifications. In fact, once these have been crystalized and approved, only proper inspection will assure the transforming of lines and words on paper, into the REALITY of a useful highway.

Unfortunately, it is easy to employ someone who is willing to work the long hours required, often under uncomfortable and trying conditions, at a reasonable salary, without too much regard to qualifications. This trend has been intensified in the last few years because the large demand for inspectors has depleted the supply of men with experience.

Yet, the inspector is the man in immediate and constant contact with the contractor, and the only representative of the owner who is continuously where the work is done. Not only does he need to know how the work should be done, and how to apply the specifications, but also how to deal with the contractor.

To effectively organize an adequate inspection force is not an easy matter. It involves not only finding the men, but also setting up a carefully planned training program in the specification requirements, and often inculcating them with the basic technical principles of the work. Continuous training is also needed to keep inspectors informed of changes, new developments, and improved methods.

Special problems develop when there are several engineering firms directing the work of many contractors on the same project, and when these groups

are involved basically with the same operations, but at different locations. In such cases, it is imperative to treat all contractors fairly and alike. Here again, training, to develop authoritative overall coordination of inspection standards and interpretation of the specifications, assures that all contractors receive the same treatment.

To implement these objectives, requires a many-sided training program, each phase of which is aimed towards meeting a specific need. Such a program should consist of large meetings at the start of construction, supplemented by small intensive group training immediately preceding a new operation, and supplemented on the job by individual training by supervisors.

The large meetings at the beginning of the work have for their purpose the indoctrination of the inspection force into the policies to be adhered to, general clarification and interpretation of specifications, and how to deal with the contractor. The line of authority should be carefully explained at such meetings, so that the inspector knows definitely whom to go to for decisions. The inspector's responsibility and authority should be carefully outlined, so that there remains no doubt in anyone's mind where he fits into the overall scheme. Questions and answers form a basic part of these meetings, to the end that the inspector goes out on the job fully aware of his duties, and how to handle problems as they arise.

The small group intensive training, scheduled immediately preceding each operation, should be more technical in nature, and should allow for plenty of discussion. The details that are presented at such meetings should be geared to the level of the least experienced. No detail is too elementary when there are several groups and several contractors involved, as this is the only assurance that everyone gets started from the same point.

The supplementation of the group training as applied to individuals is a problem for field supervisors, who are in close contact with the work of the individual inspector from day to day, and who can supplement the group meetings with actual on-the-job training as the need arises.

Only through such aids as this suggested three-step training program, can one develop an inspection force that is capable of meeting problems as they arise with equanimity, with fairness to the contractor and owner, and with a reasonable degree of assurance that the finished highway will perform as intended, require the minimum of maintenance, and will have the longest life possible under the circumstances.

It is advantageous at times to open training meetings to contractors' superintendents and foremen, so that they will become familiar with what is expected of them and how it is to be met. This also tends to reduce the dividing line which unfortunately so often develops, between contractor and inspector, and tends to create a feeling that they are both working toward the same end—constructing a highway with inherent quality to perform the uses it was planned for—such an attitude, if developed, is most wholesome.

An item that is always part of inspection, inasmuch as it is one of the duties of the inspector, is the preparation of reports. Reports are very important to acquaint a large engineering organization and the owner with how construction is progressing, theproblems that are arising, and solutions that are developed. But more important, reports form the record to be used as evidence in claims, in law suits, in cases of failures, or to supply information that will permit the determination of reasons for difficulties that may arise, often many years later, when the inspectors are no longer available and when memories cannot be relied upon.

The importance of reports cannot, therefore, be overemphasized. Reports should be carefully prepared and always prior to the time the inspector leaves his shift, so that they may be factual and not dependent on memory for the facts that need to be included. They should contain information on what happened, not only when happenings are unusual, but also when items are regular occurrences, as otherwise the report will fail to be useful as a record. Quantities, problems, solutions, discussions with the contractor, instructions received or given, etc. should all form part of the inspector's report.

To plan and conduct such training requires not only men who know their subject, but also men who are enthusiastic about and believe in the desirable results that can be attained through this activity. Supervisors of construction work using this type of quality control should have a broad viewpoint and wide experience in the various phases of design, materials, control, specifications, contracts, and should have a progressive philosophy and be sympathetic towards new ideas and methods that can be applied to their work.

Not many organizations are fortunate enough to have men with such qualifications in the training field, and it is often advantageous to call in outsiders who are specialists, or consultants who have had experience in this type of work, if best results are to be obtained.

The supervisor must be capable of administering such a control program fairly and should be capable of making the proper decisions as problems arise. He should be able to develop the proper balance among speed, quality, and cost, so as to produce the best finished highway under the prevailing conditions.

The attitude of management towards the whole problem of quality control is the key to its success. Proper specifications, qualified engineers, and the very best inspection force will fail in the end if management is not sympathetic with the program. On the other hand, a strong attitude on the part of the top executives towards the program will soon permeate the entire organization and stimulate everyone to get the best results.

CONCLUSIONS

With accelerated highway programs, higher design standards, construction through the cold winter months, increased costs, and shortages of materials and personnel, a broadened approach to quality control on large highway projects has become a necessity.

This approach is based on the concept that quality control applies not only to the materials delivered to the project, but also to the operations and procedures used to incorporate these materials into the finished facility.

Its most important feature is UNIFORMITY, which is attained through increased use of automation, "self-functioning" features, and statistical treatment of data which provides the basis for obtaining control and measuring its results.

This type of comprehensive quality control, with its individually designed and progressive specifications, its thorough training programs which provide intelligent inspection essential to converting designs and specifications into the REALITY of the finished highway, and its dynamic supervision backed by management, favors and recompenses streamlined contractor operations. It therefore expedites construction, and results in lowered costs, and in a highway that will require minimum maintenance and that will provide utmost uninterrupted use.

Paper 1627 May, 1958 HW 2

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CORRELATION OF GEOMETRIC DESIGN AND DIRECTIONAL SIGNING[a]

George M. Webb,[1] A.M. ASCE
(Proc. Paper 1627)

ABSTRACT

The directional signing must be given consideration during the earliest planning and design stages, if a freeway is to function efficiently. This requires that the engineers involved in each of these elements be fully cognizant of each other's problems.

The paper discusses these factors and presents certain basic principles for the guidance of all concerned.

INTRODUCTION

One of the most interesting developments in the last few years in the field of highway engineering has been the directional signing. This has been especially true of the rapidly developing network of California freeways. These freeways must carry large traffic volumes smoothly and with a minimum of traffic friction. To achieve this, it has been found, requires more than high design standards and elaborate signing. If a freeway is to function with maximum efficiency, geometric design and signing must be integrated. In other words, signing is not a separate item to be considered just before the freeway is ready for traffic. Rather, it is an integral part of the freeway and must be given consideration in the earliest planning and design stages.

California has been building freeways since 1940. It was after World War II, however, that the freeway program began to really take form. The tremendous growth in population and vehicle registration, experienced after the

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a. Presented at New York Convention of the American Society of Civil Engineers, New York, N. Y., October, 1957.

1. Asst. Traffic Engr., California Div. of Highways, Sacramento, Calif.

war, was also reflected in the great increases in traffic volumes found each year on the freeway system. Traffic pressure made it necessary, even in those days, to use full-scale overhead illuminated signs. Signing experience developed over the years has shown that minimum design features often could not be properly compensated for by signing alone when the freeways were operating under maximum capacity conditions. As a result, certain criteria have been formulated, the observance of which insures the development of a coordinated relationship between signing and geometric design that today's traffic load demands.

The problem in any highway organization of establishing coordination between the people responsible for the geometric design and those people responsible for signing lies in the development of an understanding by the individuals involved, of the following:

1. Principles of directional signing;
2. Relationship between geometric design and signing;
3. Correlation of geometric design and signing.

Principles of Directional Signing

The problem of helping the motorist find his way over America's intricate street and road system is becoming more and more difficult. This is due, in part, to the increased traffic volumes, to the higher vehicular speeds found on today's highways, and to the complexity of some of the modern traffic interchanges.

Someone once characterized today's motorists as falling into three types:

1) Those who know where they are going and know how to get there.
2) Those who know where they are going but don't know how to get there.
3) Those who don't know where they are going and don't know how to get there.

Information gained during origin and destination surveys has shown that the wag responsible for the above classification was more right than one would suppose. Roadside interviews confirm the fact that there are people who fall into the third group.

There are other people, evidently, who leave their homes to take a trip and never look at a map. In some cases they have a vague idea of the general direction of their destination or of which road to take. In other cases they inquire at service stations or perhaps of strangers along the way. If the traveler expects to go to his destination over strange roads and streets easily and quickly, he must use a map in order to take full advantage of modern directional signing.

The principal concern of the highway engineer is for the first two groups. The first group, composed mostly of local people on local trips, needs very little guidance. The second group, composed mostly of strangers, requires careful guidance if they are to travel without getting lost or becoming confused. It is this group that the signing effort is directed to principally. The thought here is that if the signing is designed for the stranger it will also be adequate for local people since they require less guidance.

In the past, the traditional approach has been to provide three distinctive methods of directional signing: (1) use of place names; (2) use of U. S. and state sign routes; and (3) use of cross street names. In recent years another

approach—the use of freeway names—has been used extensively in some of the larger urban areas. Each of these has its advantages and disadvantages and when they are judiciously applied, singularly or in combination, the result is efficient directional service to the traveling public.

Place Names

The oldest method of directional signing, and the one which, it is felt, provides the greatest service, is the use of place names. The use of the name of a well-known city is a quick means of identification, in the minds of many motorists, of the route and its direction.

Experience has shown that today's vehicular speeds preclude the use of more than three names on a sign. As a matter of fact, on a freeway it is very desirable to limit this to one name for each direction and in no case more than two. There are thousands of communities and cities in California, and the names of only a few can be used at any one location. Many of the tourists from out of state get little directional benefit from the use of well-known California names because of a lack of even a rudimentary knowledge, in most cases, of state geography.

Sign Routes

In addition to the use of place names to direct the traveler, a system of sign routes has been developed in the last 30 years. The American Tourist has come to depend on the sign routes. He has learned that by carefully following the route shields it is possible to travel with little or no confusion. Despite the fact he may be passing through strange territory and through many states, he knows that it is possible to travel long distances without getting lost even though the route passes through the desert, over the mountains, or through a great metropolitan area.

The two principal types of sign routes in use today are the nationwide U.S. sign route system and the individual state sign routes. Both methods of route designation use even numbers for those routes which run generally east and west and odd numbers for those which run generally north and south, although few motorists are aware of this basic characteristic. At locations where the sign route directions are different from the actual compass directions the possibility of confusion may be greatly reduced by proper type of geometric design and by use of place names to supplement the guidance given by the sign routes.

U. S. Sign Routes

The purpose of the U. S. road numbering and marking system is to facilitate travel on the main interstate lines, over the shortest routes and the best roads. Over the years the U. S. route system has been constantly altered and improved. For instance, new construction has opened up better and shorter routes which in many cases have been included by means of revisions in the system. Authority to establish and alter the U. S. numbering system lies in the hands of the Executive Committee of the American Association of State Highway Officials.

In connection with the U. S. numbering plan, it has been found necessary and expedient to establish four types of alternate routes: (1) "business"; (2) "by-pass"; (3) "alternate"; and (4) "temporary." Each of these has its place and fulfills a need. It is apparent, however, that the use of these

alternate types of U. S. route designation tends to complicate the signing problem.

State Sign Routes

The state sign route system is similar to the U. S. system except that it is for the purpose of facilitating travel on the main intrastate routes via the shortest and best roads. Unlike the U. S. route system there are no alternate state routes. Authority to establish state sign routes in California lies with the State Highway Engineer.

Cross Street Names

In urban areas many of the interchanges, as a means of providing traffic service to local people, are at cross streets. In some cases these cross streets are fairly short and lead to residential areas within the city. In other cases there are well-known cities located on the cross streets. When the names of these communities are used in signing, they not only provide directional service but they also serve to orient the motorist as he travels from one point to another.

The commuter or local person needs much less elaborate signing than does the stranger. The directional signs act mostly as a reminder to the commuter. On ordinary highways the motorist is guided by familiar landmarks such as the corner service station, grocery store, or some other distinctive object. There is considerable "sameness" about a freeway, and therefore directional signing must, to a great extent, substitute for these landmarks. There is one particular disadvantage connected with signing to cross streets. It does not give, in contrast to place names, guidance as to whether the motorist must turn to the left or right in order to arrive at his destination. In other words, a cross street name, if not used in conjunction with a place name, requires with it the use of the cardinal points such as north, south, etc. In actuality, these refer to northbound, eastbound, but for the sake of convenience and on the assumption that the public understands this, the last part of the word is deleted and just the single word north, south, east, west, as the case may be, is used. Unfortunately, there are motorists with poor sense of direction and this information may mean little to these people since some routes actually run in almost any direction for long distances even though their over-all placement may be in one general direction.

Freeway Names

In the Los Angeles area, many years ago while the freeway network was in the planning stage, names were assigned to the freeways. These names are now well-known and newspapers and maps invariably refer to freeways by these names rather than by their route numbers.

Some of the freeways have been named after a city at one terminus with the thought that this would be an aid to the traveler. This has served to complicate the signing, however, due to the fact that all freeways have two termini. For example, a motorist, trying to reach Santa Ana, can be on the Santa Ana Freeway and still be traveling away from his destination.

When two freeways cross, the signing becomes involved. Junction U.S. 99 is a lot simpler to see and comprehend than Junction San Bernardino Freeway. This latter legend, because of its length, greatly complicates the problem of designing a practical sign and of locating it on the freeway. The

question of which direction to take when using freeway names also involves use of cardinal points unless prominent and well-known place names are available for use.

The designation of different portions of the same continuous freeway with different names is a source of confusion to the motorist and greatly complicates the directional signing problems. Where freeways are named, it is best to use the same name for the entire length of a freeway from termini to termini.

Relationship Between Geometric Design and Signing

Modern highways are carefully planned to provide the greatest possible range of benefits with the least cost. To accomplish this worth while objective is fairly easy in the case of simple highways. Freeways are much more complex and the planning problems are much more involved. The highway engineer must reconcile conflicting elements (keeping one eye on the available money) with local conditions in such a way as to provide a satisfactory design. Consequently, the design of any highway project represents a well-considered compromise that has been effected only after a thorough study of what constitutes the best possible combination of all of the factors.

One of the important factors which must be considered in geometric design, along with the multitude of other considerations, is the signing. It is recognized nowadays that the signing is actually an intrinsic part of the geometric design and must be given due consideration in the planning, if the ultimate purpose of a freeway, which is maximum traffic service, is to be obtained. The thing to remember is that at most locations the directional information is set not only by the geographical position and the direction of the alignment of the intersecting roads, but also by the geometric design as well. While some designs readily lend themselves to the use of simple directional signs that provide complete information, others, in contrast, have the undesirable characteristic of requiring complicated combinations of place names, sign route numbers, cross street names, or freeway names. The result is a legend which does not accomplish its primary objective of providing quick and efficient guidance to the motorist.

To achieve maximum compatibility between the signing and the design requires consideration, during the design period, of the following: (1) route continuity; (2) traffic interchange design; (3) sign visibility. These three factors are, of course, closely related, but for the purpose of this paper a better understanding of the signing problems can be had by considering each separately.

Route Continuity

Many of the U. S. routes are transcontinental in nature and consequently some of them stretch for thousands of miles. Once a motorist has decided on which of these he wishes to travel, it is a simple matter for him to follow the road ahead and to watch for the route shields. He is generally not concerned with the place name signing within the state through which he might happen to be passing. This is probably true also of the person on fairly long trips within a state. In other words, the motorist has learned to depend on route continuity. If he continues to follow, especially in rural highways, what appears to be the main roadway, he is confident that he will also be following the sign route.

The problem of finding one's way through a great city to a specific location is often very difficult, even for a resident of that city. The modern urban freeway, however, simplifies this problem tremendously as it allows unhindered and often direct travel across the gridiron pattern of the city. A freeway network provides even greater convenience especially if a sign route system is integrated with the freeway network. Here again, however, the need becomes apparent for continuity of both the sign route and the individual urban freeway, with the urban freeway generally taking precedence over all except perhaps the most important U. S. sign routes. To accomplish this requires consideration during planning and design of the need for route continuity.

Sign Route Continuity

The practicability of providing sign route continuity at interchange locations sometimes depends on whether or not it conflicts with the geometric requirements of the estimated traffic movements. This conflict arises from the fact that the signing and geometric design requirements of that portion of the traffic stream which is composed of people who are familiar with the route, often vary considerably from those of the absolute stranger.

The freeway designer is concerned, of course, with the problem of providing a facility which will furnish, among other things, the maximum of traffic service. In any large city the number of trips by local people far exceeds those by tourists and other strangers. The emphasis in geometric design, then, is to provide freeway facilities which conform to the desires of the majority of road users. Unless great care is taken, however, this may result in traffic interchange designs which do not provide route continuity. In other words, the stranger, in order to stay on the sign route he needs to follow, must leave what appears to be the <u>main roadway</u>. Past experience has shown that such a situation will result in some motorists losing their way even though ample signing is provided.

When the local turnoff from a sign route or an important named freeway requires as many or more lanes than the through traffic, the geometric features should be designed, whenever possible, to provide a branch connection, and the connecting lanes to the local road should definitely give the impression that they are the turnoff lanes. The purpose of this is to give the appearance that the highway carrying the through route number or freeway name is a major road and not a turnoff. This can be accomplished either by careful manipulation of the geometric design or by pavement differentiation, or by both methods. See Figures 1A, 1B, 1C, and 1D.

A branch connection is defined as a connection in which one or more lanes are dropped off or added or where two roadways split or merge. This is illustrated by Figure 2. Branch connections are necessary where large traffic volumes enter or leave a freeway.

With traffic volumes and traffic speeds on metropolitan freeways, the motorist needs to know of an impending turnoff, particularly a branch connection, about one mile in advance so that he can move over to the proper lane preparatory to the actual turnoff. To prepare the motorist for the exit movement, he must be alerted well in advance by signing, and the sign message must be repeated. This is extremely important on heavily loaded freeways.

Figure 1A

Lack of route continuity in a traffic interchange between freeways with well-known names is illustrated by Figure 1A. Note that under this arrangement the motorist wishing to continue on the Harbor Freeway must leave what appears to be the main road.

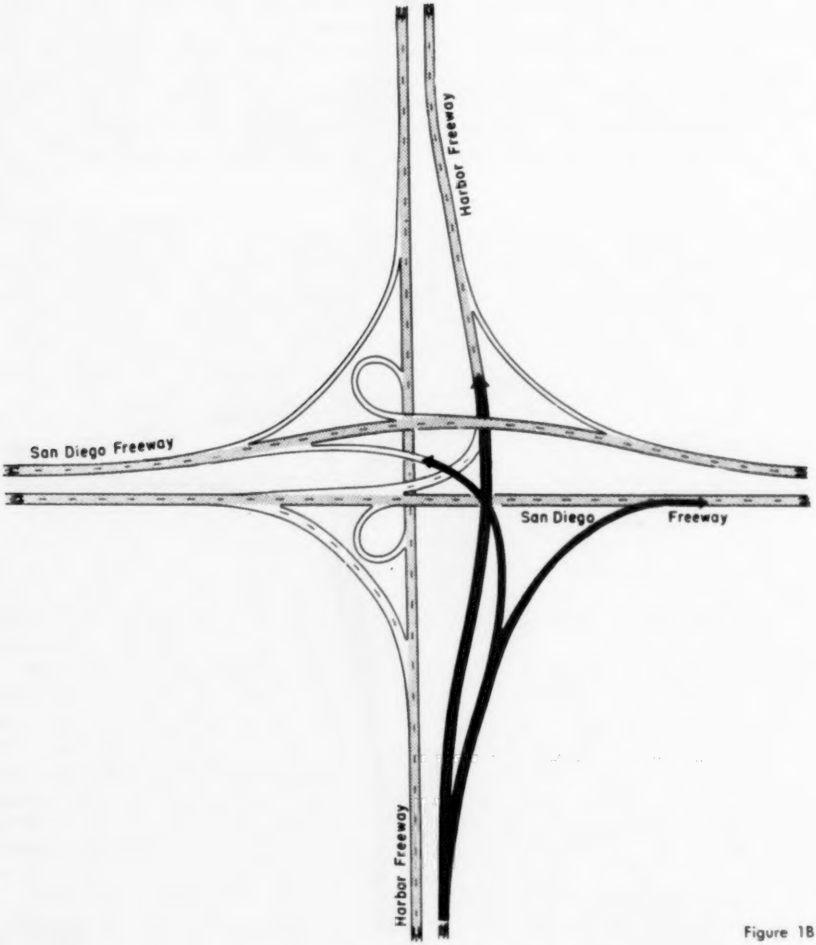


Figure 1B represents a more desirable design in that the through movement is continuous and natural.

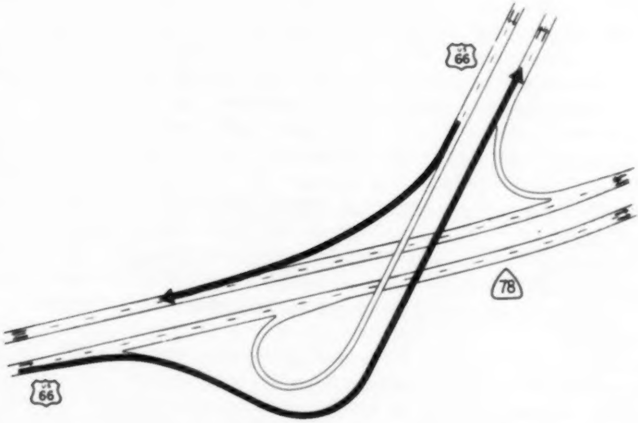


Figure 1C

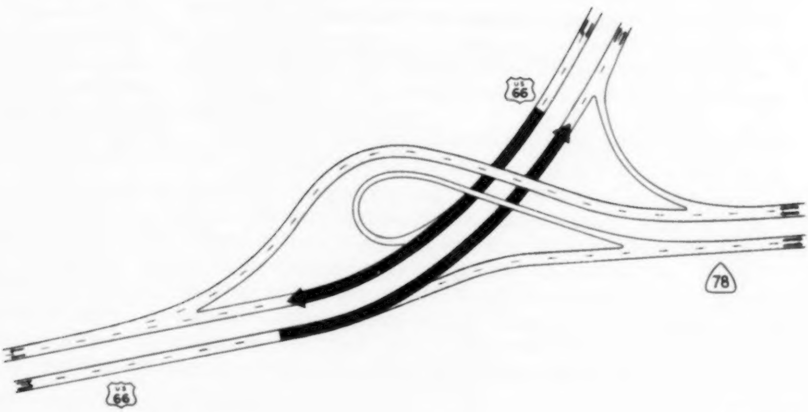
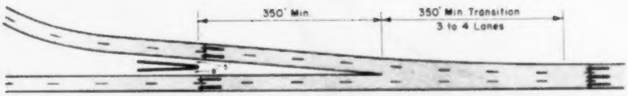
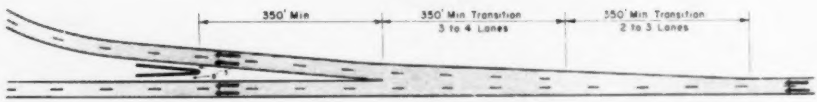


Figure 1D

In the interchange design illustrated by Figure 1C, the highway carrying the through route number (U. S. 66) appears to be a turnoff from the main road. Contrast this with the design shown in Figure 1D which takes into consideration the requirements of sign route continuity for U. S. 66.



BRANCH CONNECTION – 3 LANES TO 4 LANES



BRANCH CONNECTION – 2 LANES TO 4 LANES

Figure 2

Typical branch connections for diverging traffic.

Interchange Design

The interchange of traffic, in the case of an intersection of two conventional highways, is accomplished easily and with comparatively little expense by the intersection at grade. The intersection of a freeway with a cross road or with another freeway, on the other hand, is much more complex and the planning problems are much more involved. The same parallel may be drawn between the problem of signing for ordinary roads and for freeways. For instance, the signing requirements for an ordinary road with intersection at grade are easily satisfied. This is because all 12 vehicular movements can be made directly and naturally. Frequently there are topographical or man-made features which make it very expensive to build a traffic interchange that includes provision for all of the traffic movements. In many cases it is expedient to eliminate some of the minor movements in order to provide an adequate path for some of the major movements. How well these truncated designs perform depends a good deal on the signing requirements.

In an urban area, it is not always advisable from the standpoint of traffic operation or economically practical to provide for all movements at every interchange. This is true especially where a major freeway intersects a local cross street. Sometimes ramps for minor movements and auxiliary connections for local access may be left out at one interchange and provided for at another interchange, or local streets may be used as part of the interchange. Extra travel distance for minor movements is subordinate to ease of operation on the freeway. However, when two major freeways or sign routes intersect, it is preferable, whenever possible, to provide for all 12 movements at the interchange. This is important, not only from the standpoint of proper signing, but also as a means of providing the necessary flexibility of operation of the freeway network, both during emergencies when a section of the freeway may be closed, and in the future when traffic flow may vary considerably from estimated design volumes.

A basic principle in geometric design is that the final and crucial test of an otherwise satisfactory design lies in the signing. If a traffic interchange layout does not lend itself to proper signing, it is not a good design.

To properly evaluate the importance of dove-tailing the signing and the interchange design requires an analysis of the signing with regard to the following: (1) types of interchanges, (2) ramp location and design. Here again, two closely related subjects are discussed separately, purely for the sake of clarity in regard to the problem of providing good directional signing for the motorists on the freeway and for the motorist who is trying to find his way onto the freeway from the city street or county road network.

Diamond-Type Interchange

A simple and inexpensive way of providing for all types of vehicular movements at the intersection of a freeway and a cross road is through the use of a diamond-type interchange. See Figure 3. When two freeways intersect, this type of interchange cannot, of course, be used because it requires a crossing at grade (left turn) on the cross street.

To the geometric designer, the diamond-type of interchange has obvious advantages and disadvantages. However, when this type of interchange is used, the problem of providing proper guidance to the motorist as he travels along the freeway is a simple one. The traveler must be told that he is approaching a turnoff (Fig. 3) (point A) and it matters little with this type of design whether place names, sign route numbers, or a cross street name are used to inform

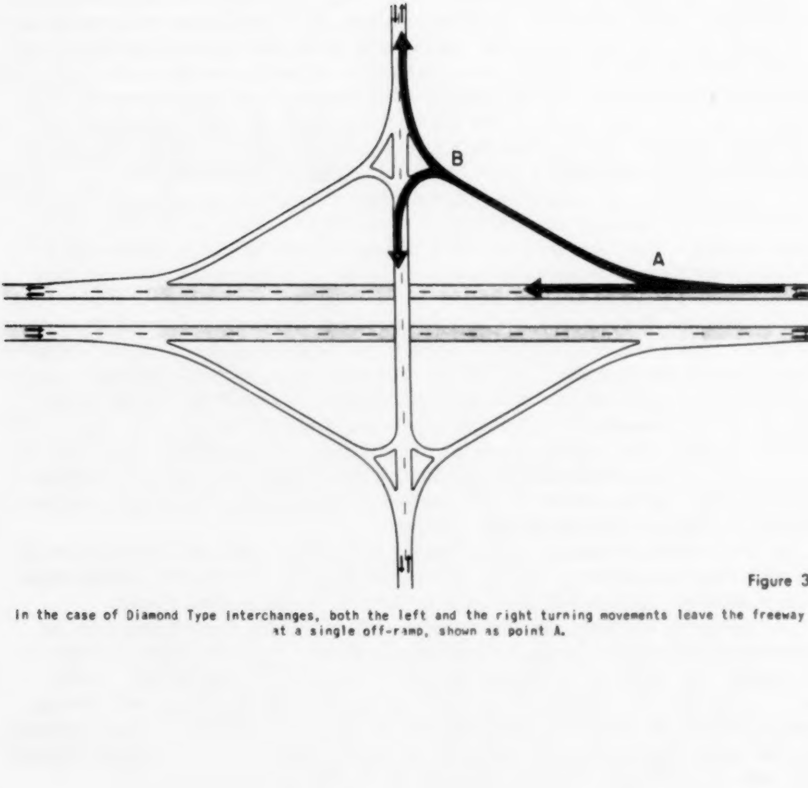


Figure 3

In the case of Diamond Type Interchanges, both the left and the right turning movements leave the freeway at a single off-ramp, shown as point A.

him of this fact. At point B in Figure 3 it is necessary to provide further information to allow the motorist to determine whether he should turn left or right. It should be recognized that the signing problems at points A and B are quite different. In one case the motorist must read and comprehend the message (sometimes called dwelling time) while traveling at high speed among the hustle and bustle created by the traffic on the freeway. At the other (point B) the motorist is usually traveling much slower and under less trying conditions. Consequently, a more detailed and complex message can be received and acted upon by the motorist at this point.

Cloverleaf Interchange

The four-quadrant cloverleaf interchange (Fig. 4), with a collector road, presents the same basic type of problem with respect to signing. The difference is that further guidance must be presented at point C.

The four-quadrant cloverleaf interchange without a collector road (Fig. 5) requires an entirely different approach to directional signing. The reason for this is that the absence of a collector road requires the motorist be supplied with enough directional information so that he can decide which of the two exits he must use. In other words, he has a double decision to make while traveling on the freeway. The first is whether this is the interchange which leads him to the cross road which he is seeking and second, as previously mentioned, which of the two exits leads to the direction of travel he must use. The collector road also makes it possible to provide signing to the second exit further in advance without overlapping the first exit.

To illustrate the comparative signing problems for a four-quadrant cloverleaf, with and without collector roads, please refer to Figures 6, 7, and 8. These diagrams allow a quick comparison to be made of the signing when place names, sign routes, freeway names or cross road names are to be used to designate an off-ramp which leads to a cross road. With regard to the cloverleaf design without collector road, it may be noticed that where prominent place names can be used (Fig. 6) the average motorist should have no difficulty in orienting himself. However, when sign routes or street names are involved (Figs. 7 and 8), the motorist must be able to orient himself by the cardinal directions. This can be a cause of confusion at times because the cardinal directions refer to the general lay of the sign route which may not coincide with the actual compass direction at any given location.

The fact that at the second gore of a collector road the motorist can see and comprehend a more complicated and detailed message (due to slower speeds and less traffic pressure), is an important advantage for this type of interchange design. There are cases where it is necessary to use a sign at this location which utilizes a combination of place name, sign route number, and freeway name. Locations where this type of signing is necessary, occur where the sign route may be in an east-to-west direction even though it passes generally from north to south. At points where there is apt to be confusion, because of such complications, it is best to provide the full compliment of information.

Hybrid Interchange

One or more of the left-turn movements at the intersection of two freeways may be of such magnitude as to preclude the use of a cloverleaf design because of traffic capacity limitations of the loop. One type of interchange design to handle this situation is illustrated by Figure 9. The left-turn ramp

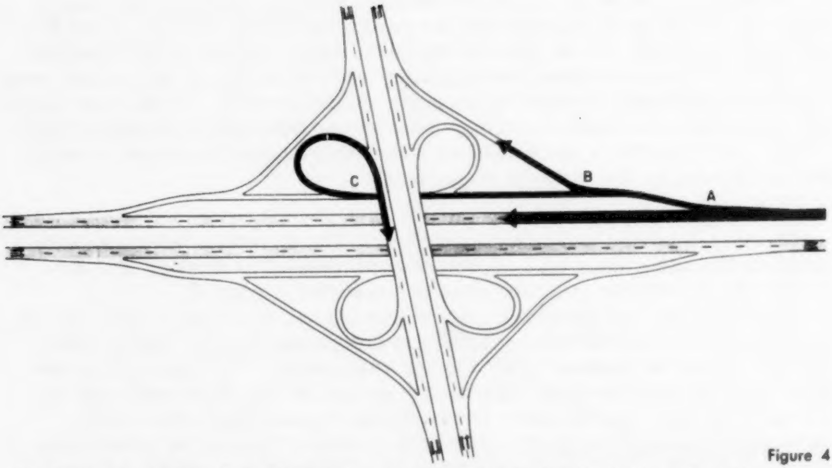


Figure 4

The four-quadrant cloverleaf with collector road is similar to the diamond type, from the signing standpoint, in that a single freeway exit, point A, is used for both turning movements to the cross street. Separation of traffic bound for opposite directions on the cross street occurs on the collector road out of the influence of through traffic.

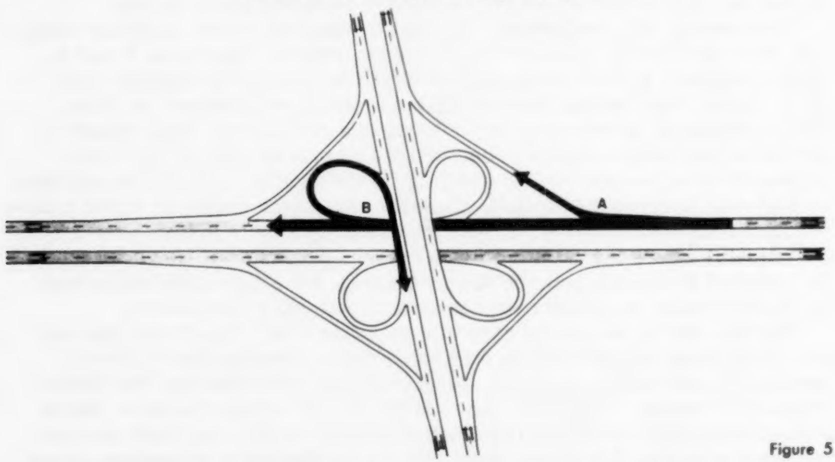


Figure 5

A four-quadrant cloverleaf without collector road. Note that separate exits, point A and point B, are provided for each turning movement. Due to the absence of a collector road, the driver seeking the cross street must determine while still on the freeway which of the two exits he wants.

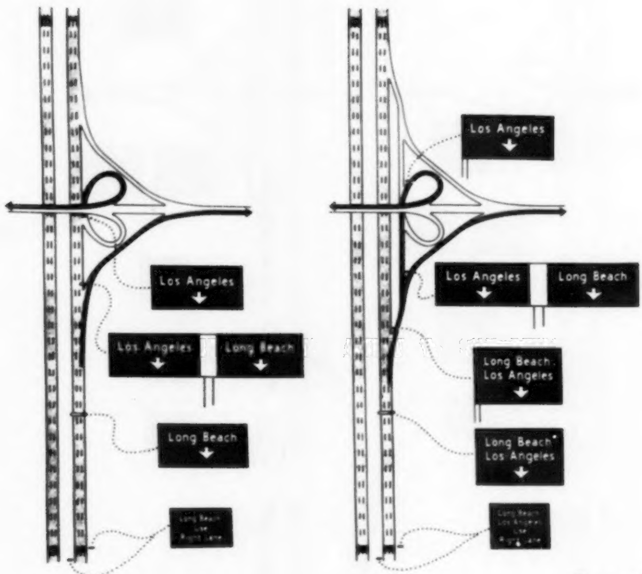


Figure 6

A comparison of the problems involved in signing four-quadrant cloverleaf interchanges without collector roads, left, and with collector roads, right, is illustrated in Figure 6, using place names; Figure 7, using sign routes; and Figure 8, using cross street names. Where place names can be used, as in Figure 6, the advantages of a collector road, from the signing standpoint, are not as pronounced as in the cases where sign routes and cross street names are involved.

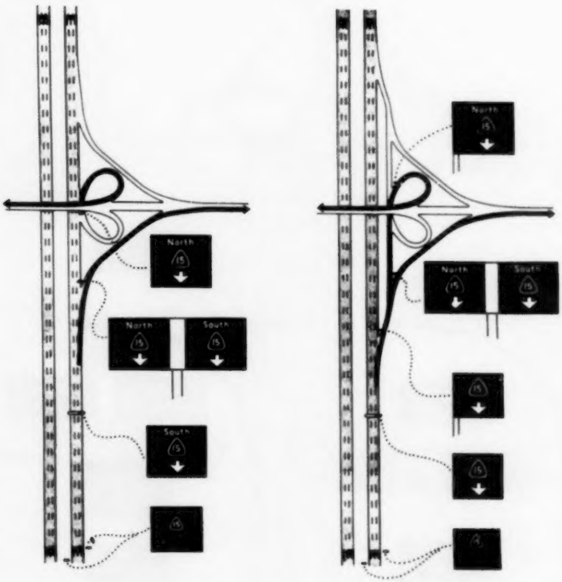


Figure 7

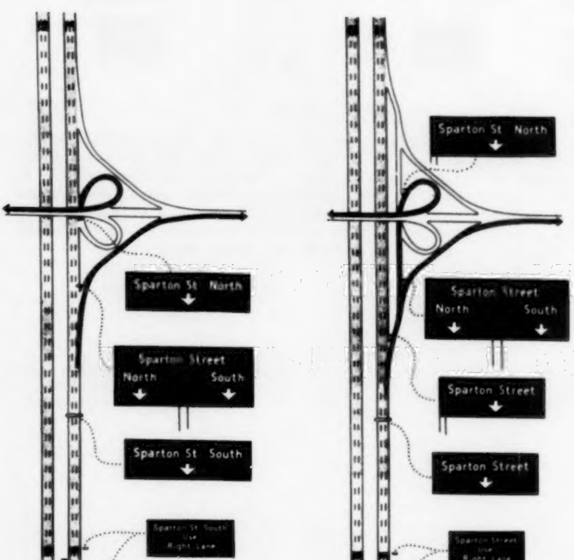


Figure 8

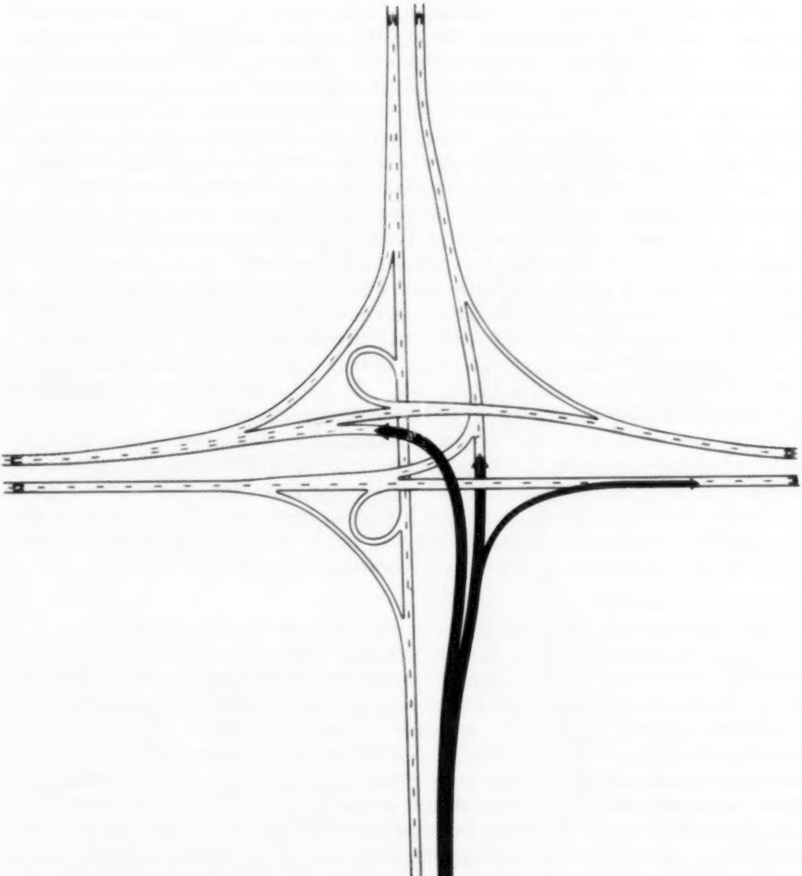


Figure 9

Figure 9 illustrates an interchange design utilizing both direct and loop connections. The signing problems for the solid portion are basically similar to those present at a four-quadrant cloverleaf without collector road, although the positioning of exits on opposite sides of the road does permit somewhat better advance notification of the two turn-offs. However, when both legs of the cross facility carry the same name or route number, a more satisfactory and simplified type of signing can be supplied, if the design includes a single exit to handle both movements.

takes off on the left side to allow a more direct movement. This arrangement, because of the separate exits for left and right turning movements lends itself to simple and effective signing when two prominent place names are available for use on the signs at each exit. This is also true when the cross street or freeway has a different name on each side of the interchange.

When the cross street or highway carries a sign route or the same name on both sides of the interchange the signing can be simplified if both movements are taken off the freeway at one exit. However, the hybrid interchange, as illustrated by Figure 9, which includes both direct and loop movements, does allow better advance notice to the motorists because one exit is on the left and the other on the right. When there are two exits on the same side, as in the case of the cloverleaf without collector road, the motorists who need to use these two exits must be directed to the right lane well in advance. Each exit requires a different legend and consequently, because of the possibility of confusion, it is generally best not to provide advance signing for the second exit until the motorist has passed the first exit. Also, when a left-hand exit is fairly close to a right-hand exit, the two separate legends do not conflict to the same degree because one refers to the left lane and the other to the right lane. There is the additional advantage of being able to use a four-name legend, two over each lane, whereas with two right-hand exits, only two legends can be used effectively. To avoid operational difficulties at left-hand exits additional signing is generally necessary.

There are locations where an interchange is needed to take care of three or four left-turn movements which must be given direct connections. An example of this is shown by Figure 10. The south approach, represented by the solid portion of this design, presents the same basic signing problem as the four-quadrant cloverleaf without collector road. In this case, however, the left-turn exit is placed before the right-turn ramp, which is unusual.

Directions by Arrow

The use of the up-arrow in highway signing is of long standing. The directional signs in the early days of the auto were often located in the intersectional area to which they applied. However, as the roads were improved and as vehicular speeds increased, it was found necessary to move the directional signs to positions in advance of the intersection. But it is undesirable to move a directional sign containing an up-arrow too far in advance of an intersection. There are instances where this has been done and where motorists have become confused and actually turned off the road into a roadside ditch under the false impression that they were following a road connection. In any case the big disadvantage of the up-arrow is that by moving the sign too far in advance, the obvious connection between the sign and the ramp to which it applies is lost. This inherent limitation of the up-arrow, which indicates direction, is not shared by the down-arrow which indicates proper lane.

The requirement today for directional signing far in advance of the actual point of turning has led to the use of the down-arrow because of its adaptability for this type of use. The problem of providing positive guidance at interchanges where a left-hand take-off or a branch connection must be employed, is also greatly simplified by the use of this signing device. The advantages of a down-arrow in a case of this kind are clearly illustrated by Figures 11 and 12. Here again, as previously, the problem is shown with place names and sign routes. The use of a cross street name in conjunction

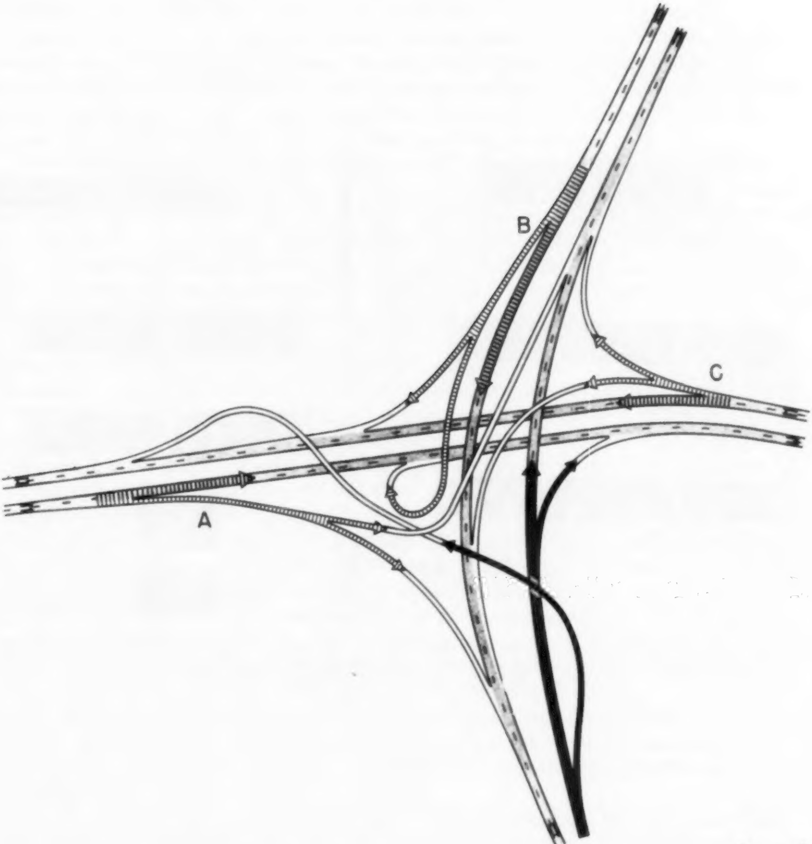


Figure 10

A fairly uncommon type of interchange connection is one in which the left-turn movement leaves the freeway on the right in advance of the right turn-off ramp, as shown in the solid portion of Figure 10. Insofar as signing is concerned, this type of arrangement presents problems similar to that of the four-quadrant cloverleaf without collector road. Unless it is possible to direct to prominent place names, this type of design is difficult to properly sign. The hachured portions (A, B, C) indicate a preferable type of design.

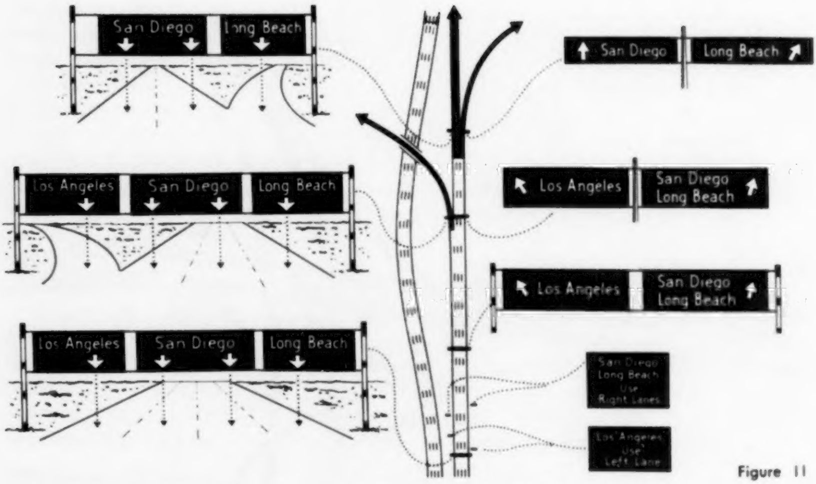


Figure II

The need for a positive indication of the proper lane well in advance of the turnoff, has led to the use of the down-arrow on overhead directional signs. The advantages of this type of arrow, as compared to the up-arrow, are illustrated by Figure II, using place names.

with the freeway name is demonstrated by Figure 13.

Ramp Location

The modern freeway, when carrying a full load of vehicular traffic, requires a signing system which provides easily understood directions for the traveler. These directions should be given well in advance so that the individual motorist will have plenty of time to move from one lane to another with as little friction as possible. To that end, ramp location, design, and signing must be coordinated to allow easy and unhurried merging and weaving maneuvers to take place. Experience has shown that certain minimum distances are needed between ramps if this is to be achieved.

It is important, from a signing standpoint, to have enough space between off-ramps because of the necessity of providing adequate advance directional information to the second ramp. The best procedure is to direct the motorist into the proper lane, which may be either the left one or the right one, only after the motorist has passed the gore of the preceding exit, especially where the exits are both on the same side. The thought here is to prevent the possibility of having motorists turn off at the wrong exit.

The spacing needed between ramps will depend on the number of freeway lanes, the number of turnoff lanes, and the relative location of one ramp to the other. The three common ramp arrangements are shown in Figure 14. It is good practice, when feasible, to require a minimum of 1,000 feet between points of gores on freeways and 600 feet between a freeway gore and a collector road gore. These distances are desirable so that the motorist has full "dwelling time" after he has seen the sign message. In addition, there is less possibility that the sign ahead, which applies to the following ramp, will inadvertently mislead motorists into taking the preceding turnoff since the large overhead signs ordinarily can be seen for over 1,000 feet.

The positioning of ramps cannot be based on an inflexible set of rules because of the complexity and the number of elements involved in the engineering decision necessary for proper location and design of a freeway. When a rural freeway crosses another road, it is usually possible, because of the absence of buildings, etc., to design a traffic interchange which allows all 12 traffic movements. In some cases the location of the freeway can be shifted to take advantage of a particular area around a portion of the intersecting road which will permit, because of favorable topographical conditions, a full interchange to be built.

There are instances, however, where it is impractical to build a unified and compact traffic interchange. This is especially true in metropolitan areas where ramps are difficult to locate and the main effort, on the part of the engineer, is directed to the objective of providing the maximum traffic service. The urban freeway, for these reasons, seldom has complete interchanges. More often, it is only possible, at cross streets, to provide partial interchanges. In many instances the city street or county road system must, of necessity, become a part of the interchange area which may include a large area. This type of design has been called a "pulled-apart" interchange.

It should be recognized, however, that the "pulled-apart" interchange adds greatly to the problem of providing guidance for those motorists who are strangers and who wish to leave the freeway and then return. (See Fig. 15A.)

There are examples of older interchange design which have resulted in such a labyrinth layout that few strangers could ever hope to find their way through it despite the most earnest effort to provide adequate signing. A

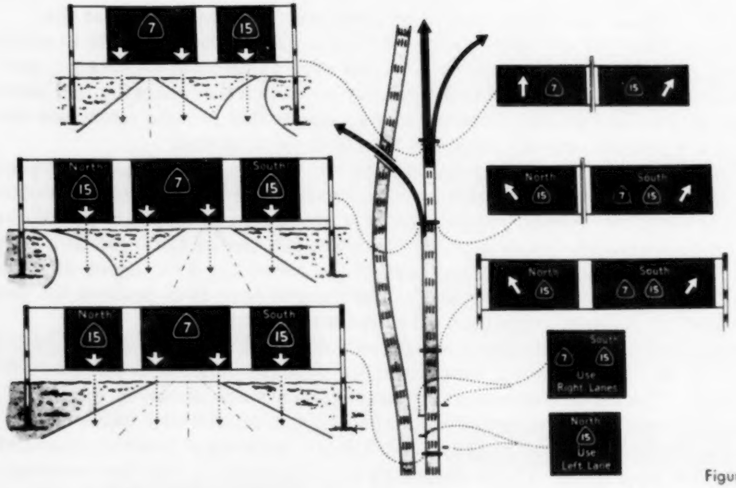


Figure 12

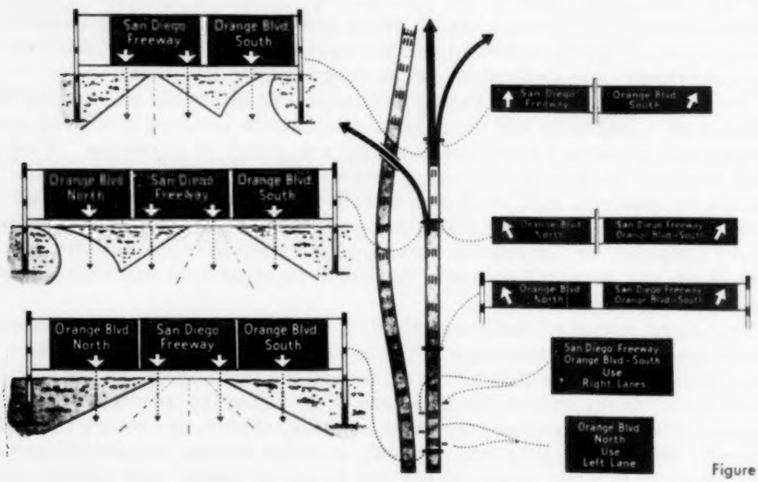


Figure 13

The advantages of the down-arrow on overhead directional signs, as compared to the up-arrow, are illustrated by Figure 12, using sign routes, and by Figure 13, using freeway and cross-street names.

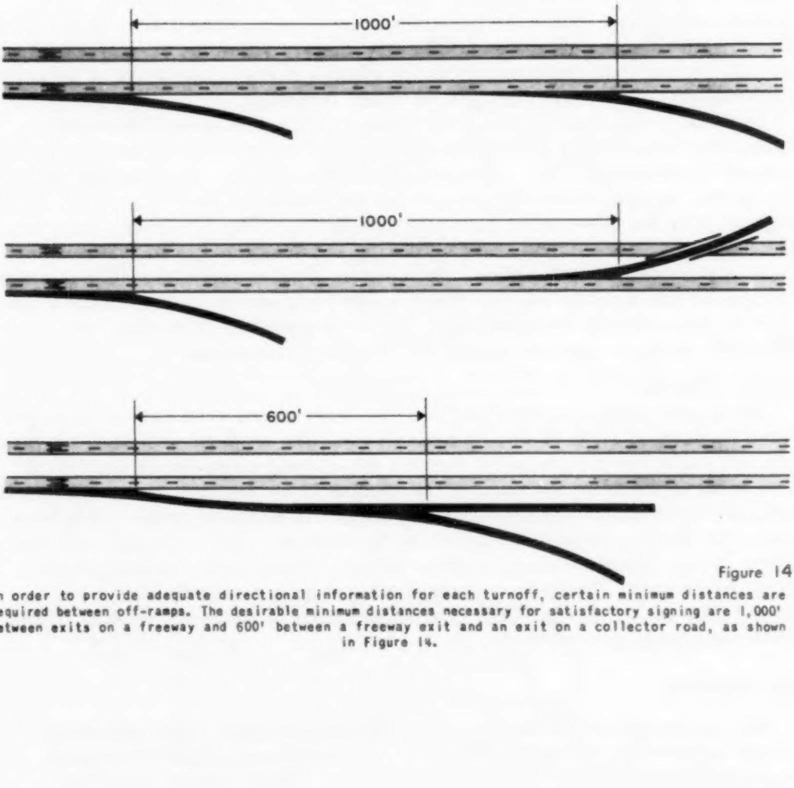


Figure 14

In order to provide adequate directional information for each turnoff, certain minimum distances are required between off-ramps. The desirable minimum distances necessary for satisfactory signing are 1,000' between exits on a freeway and 600' between a freeway exit and an exit on a collector road, as shown in Figure 14.

good illustration of such an interchange is shown by Figure 15B. The highway engineer has come to the realization that the extra first cost involved in creating a simpler and more practical interchange pays off in greater traffic service and in reduced road user operating costs.

Ramp Design

The urben freeway consisting of six or eight lanes requires a more frequent use of overhead illuminated signs. The illuminated single post, T-shaped, commonly called the butterfly, type of sign, when placed in the gore, has proven to be a real aid in helping the motorist find his turnoff. This type of sign has the happy characteristic of clearly marking the point of bifurcation. Consequently, its use is required on urban freeways.

In rural areas, especially where there is little background distraction caused by commercial lighting or signing, the use of reflectorized signs has proven to be satisfactory. At some locations, however, where a long legend is needed, the standard width of gore is too narrow to allow placement of the sign up near the nose of the gore where it will be most effective. This situation requires special consideration during the design stage so that a wider gore is provided when feasible. Here again is an example of where the signing and design must be coordinated if proper and effective directional guidance is to be provided for the motorists. In cases where a wider gore cannot be obtained, the gore sign can be placed overhead, if necessary.

Width of Median

There are many freeways where only a very narrow median could be provided because of right of way complications. The modern multilane freeways (six and eight lanes especially) require directional signs facing traffic on both sides of the traveled way. If the median is too narrow, there will not be adequate space there for reflectorized signs. In addition, some of the overhead sign bridges require a support in the median. It is inadvisable to place a sign bridge leg in a narrow median because of the traffic hazard which might be created. These important signing requirements should be recognized in the planning stage and, if at all possible, a minimum median width of 22 feet should be provided.

Sign Visibility

The need to give motorists plenty of advance warning of an impending turnoff under today's traffic conditions has been emphasized by the peak hour congestion on some California freeways. There are two ways that this advance warning can be provided. One way is to increase the legibility of the signs by making the letters larger and the second way is to move the signs to a position further in advance of where the message is to apply.

The size of letters that can be used on highway signs is limited by the size of signs which can be placed on the available space on the highway right of way. The practice in California on state highways on overhead illuminated signs is to use 18-inch capitals and 12-inch loop heights. This is the maximum size letter which can be used to best advantage over the traveled way and over the various off-ramps. Any larger letters would take up more horizontal space than is generally available.

There are practical limitations also as to how far in advance a sign can be placed. On modern urban freeways, with the traffic requiring frequent off-ramps, there is the danger of misdirecting traffic if the individual

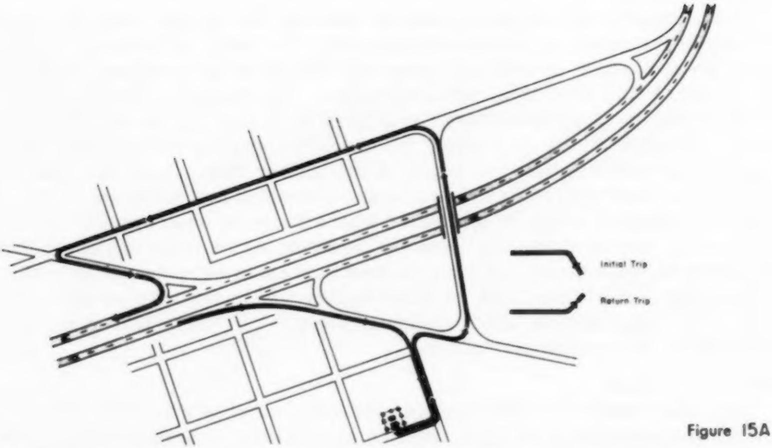


Figure 15A

The "pulled-apart" interchange, such as that represented by Figure 15A, can be somewhat confusing to the stranger who, having left the freeway and transacted his business, wishes to return to his point of origin.

Figure 15B

Complicated interchange designs are sometimes the result of location controls which dictate the position of the freeway, as in the case of Figure 15B. In this instance, a more desirable type of interchange layout could not be provided, because the freeway was located adjacent to a railroad track in the immediate vicinity of a major cross street. In such cases, fully adequate signing is not possible.

messages are not crystal clear with respect to legibility, visibility and intent all at the same time.

Sign Placement

Past experience has shown that the location of each sign must be carefully chosen if its visibility is to be unimpaired. The effect of horizontal and vertical curves must be considered along with the effect of overhead bridge structures which may block the view of the sign. The engineer should not lose sight of the fact that oftentimes the geometric design may be so arranged, at no or little extra cost, to provide for full-scale sign visibility. The use of a sign bridge directly over the traveled way rather than a butterfly type at the side of the road may reduce or eliminate confusion in a situation of this kind. The placement of a sign at a location where it can be seen across a horizontal curve may lead to confusion. Another situation which must be guarded against is where the directional sign can be seen across an interchange area with the result that motorists may be mistakenly directed by the sign on another roadway. Full advantage is taken, whenever possible, of the overhead bridge structures as a support for signs.

Vertical Curves

The placement of an off-ramp beyond the summit of a vertical curve, even though standard stopping sight distance is provided, is sure to cause confusion. The best procedure, of course, is to avoid a situation of this kind during the design stage by moving the off-ramp or moving the vertical curve to provide more sight distance. See Figure 16. If this cannot be done, this type of design, especially if a branch connection is involved, must be compensated for by greater use of overhead signs. The use of a butterfly illuminated sign in the gore with possibly one or two sign bridges will generally reduce any operational problems to a minimum.

The ideal situation is where it is possible to provide the motorists with an off-ramp in which full visibility is created for both the length of the ramp itself and for the signing which pertains to the ramp. See Figure 17. In this way, positive guidance is given to the motorist because he sees both the sign and the ramp in full view before the turnoff point is reached. He will then proceed with confidence and there is less likelihood of hesitation and last-minute changes of direction.

Correlation of Geometric Design and Signing

The proper approach, it has been found, in correlating the geometric features of the roadway with the directional signing, is to establish clear-cut advance planning objectives and proper design criteria. These will act as a guide to the people involved and will help them keep in mind the long-range purpose of good highway planning. The end result will be an efficient and smooth-working network of highways which is a first-rate indication of careful thought during all phases of planning and design. Simple and effective directional signing, after all, is merely a reflection of good planning and design because the signing, in the final analysis, is an integral part of the highway.

Highway Network

There is little doubt that eventually a nationwide network of freeways will be built over some of the major U. S. sign routes. It is also very likely that

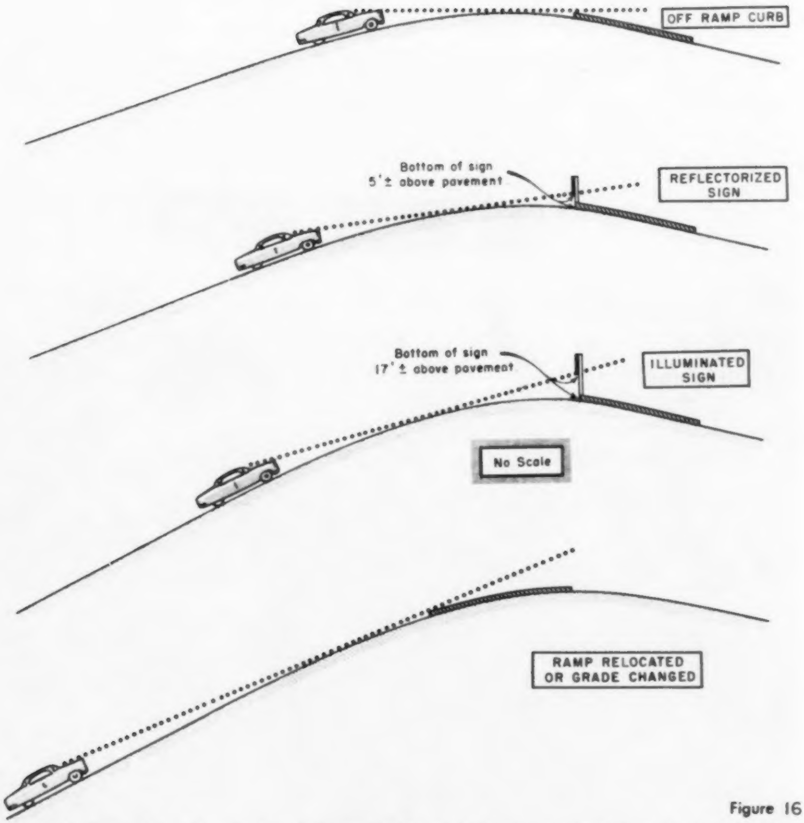


Figure 16

The positioning of an off-ramp beyond the crest of a vertical curve, as shown in the top sketch of Figure 16, seriously impairs visibility to the off-ramp and should be avoided, if possible. Although the condition may be partially offset by means of signing (next two sketches), the most satisfactory design is one which provides full visibility to the ramp (lower sketch).

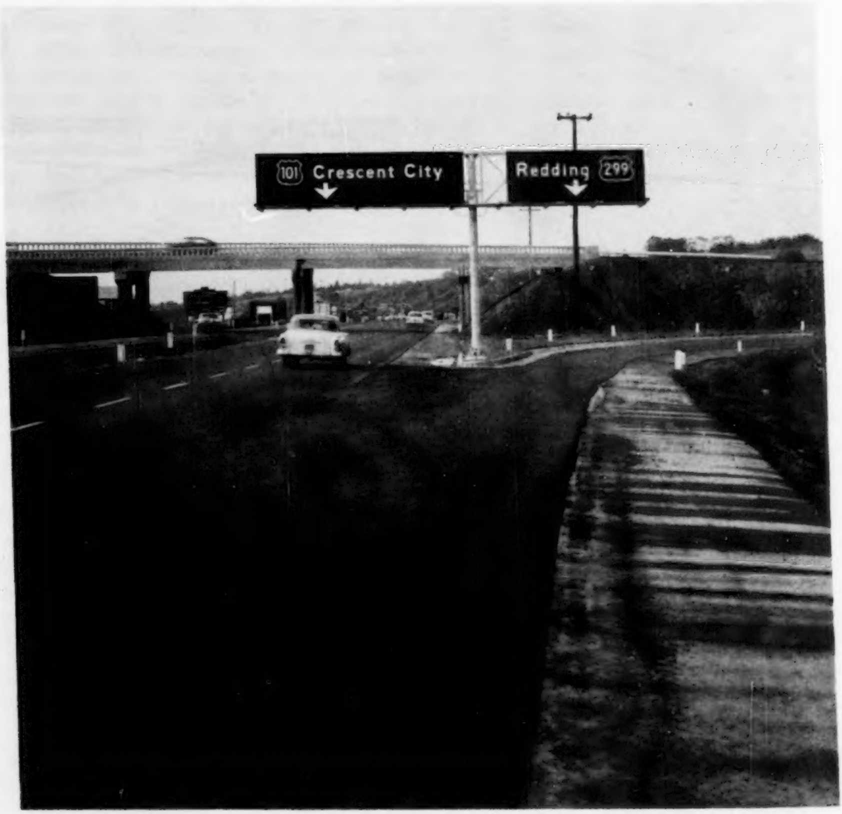


Figure 17

Positive guidance is given to the motorist when he can see both the sign and the ramp in full view before the turnoff as in Figure 17.

some day most states will be able to build a fairly complete network of good roads to serve the needs of intrastate travel. Eventually there will come into being throughout the USA, a comprehensive system of freeways, both rural and urban, which will make the movement of people and goods even more efficient.

The vehicular travel over such a network of roads, as envisioned above, will consist of trips of all lengths with the shorter trips by local people predominating over the much smaller percentage of longer trips by strangers. The prime purpose in developing this vast network of fine roads is to create a road system which will provide the most benefit to the Nation, to the state, and to the community through maximum traffic service to the road user.

There is a danger, however, that the highway engineer, in his preoccupation with the job of providing the maximum in traffic service, will neglect the smaller volume of long-distance travel by strangers. The long trips, even though they usually comprise a smaller percentage of the traffic stream, are important. The best approach, it is felt, is to plan for an eventual network which will take care of the major traffic movements, but which will, at the same time, allow the long-distance traveler to also pass over the system with certainty. To this end, it is desirable that the advance planner give constant consideration to the following:

1. Eventual development of a unified and logical road system based on U. S. and state sign routes.

2. Placement of the general route location, wherever possible, and with due consideration of other factors, so as to intersect other sign routes at favorable locations and thus allow the geometric designer to create traffic interchanges which will permit proper signing.

3. Consideration of the problem of directing motorists during periods of stage construction when various routes are being developed piece by piece.

Signing Design Criteria

The first step in developing a working relationship between the people who are doing the designing and the traffic people who are responsible for the signing is to bring about an understanding of common problems. The signing problems of any project must be brought to the attention of the geometric designer when the project is in its earliest design stages. At that time, consideration should be given to the following items:

1) Need for providing continuity for sign routes and freeways.

2) Allowance for all 12 traffic movements, if at all possible, at interchanges where two sign routes or two freeways intersect. A reasonable amount of circuity of travel is permissible for the minor movements if these movements can be properly signed so that traffic flow from one highway to the other is possible.

3) The avoidance of "pulled-apart" interchanges because of the difficulty they create in directing traffic back onto the freeway. Simple and compact interchanges, even when the first cost is a little more, are preferable.

4) Provision for adequate distance between ramps. This consists of 1,000-foot minimum between exits on the freeway and 600-foot minimum between a freeway exit gore and a collector road gore. Figure 14.

5) Provision for unimpaired visibility, whenever possible, for exit ramps and their signs.

6) Allowance for adequate gore width on rural freeways where reflectorized signs are to be used.

7) Avoidance of ramps for local traffic movements, within the interchange area when two freeways intersect, because of complicated design and signing.

8) Provision for collector roads with cloverleaf-type of interchanges where feasible.

CONCLUSION

Directional signing should be designed so as to provide guidance to all types of motorists. At any particular location these will range from commuters who travel the road every day to people who have never been over the road before. The critical element, with regard to signing, in the traffic stream, even though it be only a small portion of the total, is the stranger. If directional signing is adequate for the stranger, it will also be adequate for the local motorist. In any case, the average motorist, if he is to venture away from his usual haunts without getting lost, must use a map for there is no way to provide enough signing which will enable a driver to find his destination merely by looking for signs without some knowledge of the geographical location of the place he wants to find.

The principal means of directing traffic is through the use of place names, sign routes, and street and freeway names. The greatest aid to the really long-distance traveler is the sign route. The development of a comprehensive highway network, in conjunction with a logical and well-planned sign route system, will prove to be a great aid to the motorist. To provide the best possible guidance, however, requires that the signing be coordinated with the planning and design. To accomplish this, the people involved with each of these elements must be fully cognizant of each other's problems. It is also necessary that definite rules and objectives be laid down for the guidance of all concerned in order that signing requirements be given full consideration along with other planning and design criteria.

The proof of the success of any cooperative project, such as a modern freeway, lies in the quality of the final product. A smooth-operating and efficient highway network is evidence of the study that has gone into its development. Effective directional signing is an integral portion of a highway and is an indication of farsighted planning and carefully integrated design.

REFERENCES

1. California Division of Highways, Planning Manual of Instructions (Part 8) Traffic, and (Part 7) Design.

2. George M. Webb, Directions for the Traveler, California Highways and Public Works, May-June, 1956.

3. George M. Webb and R. J. Israel, Freeway Ramps, California Highways and Public Works, September-October, 1955.

4. J. C. Young, Building Safety Into Highways, speech delivered at Governor's Safety Conference in Sacramento on December 7, 1950.

5. Sam Helwer, Traffic Interchange Design, California Highways and Public Works, November-December, 1950.

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Proceedings of the American Society of Civil Engineers

INTEGRATED PLANNING OF HIGHWAYS AND CITY STREETS[a]

Guy Kelcey,[1] M. ASCE and George Leland,[2] A.M. ASCE
(Proc. Paper 1628)

SYNOPSIS

An illustration of integrated planning of a system of arterial highways and city streets in a metropolitan region. Consideration of other aspects of development to insure the future growth and economic well-being of the region.

INTRODUCTION

It has recently been suggested that highway engineers give too little attention, in planning urban freeways and expressways, to many of the social and economic factors which are important to the present and future welfare and growth of our cities.

While there may be instances where this has been the case, the exact opposite is true in much of the highway planning in the urban areas of many of our states. If there have been cases where significant factors of community development have been overlooked in selecting the location and planning the characteristics of major new highways, it may very well be that the highway engineers have been limited in making their studies by inadequate funds.

The master plan of highways for the Lowell-Lawrence-Haverhill metropolitan region of northeastern Massachusetts has been selected as an illustration of highway planning which has been integrated with city street systems

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1. Partner, Edwards and Kelcey, Engrs. and Consultants, Newark, New Jersey.

2. Associate, Edwards and Kelcey, Engrs. and Consultants, Newark, New Jersey.

and with other aspects of community development. This survey illustrates the care taken by state highway officials in Massachusetts to insure that new freeways and expressways are located to serve the present and future development of communities they traverse to best present and future advantage.

The Region

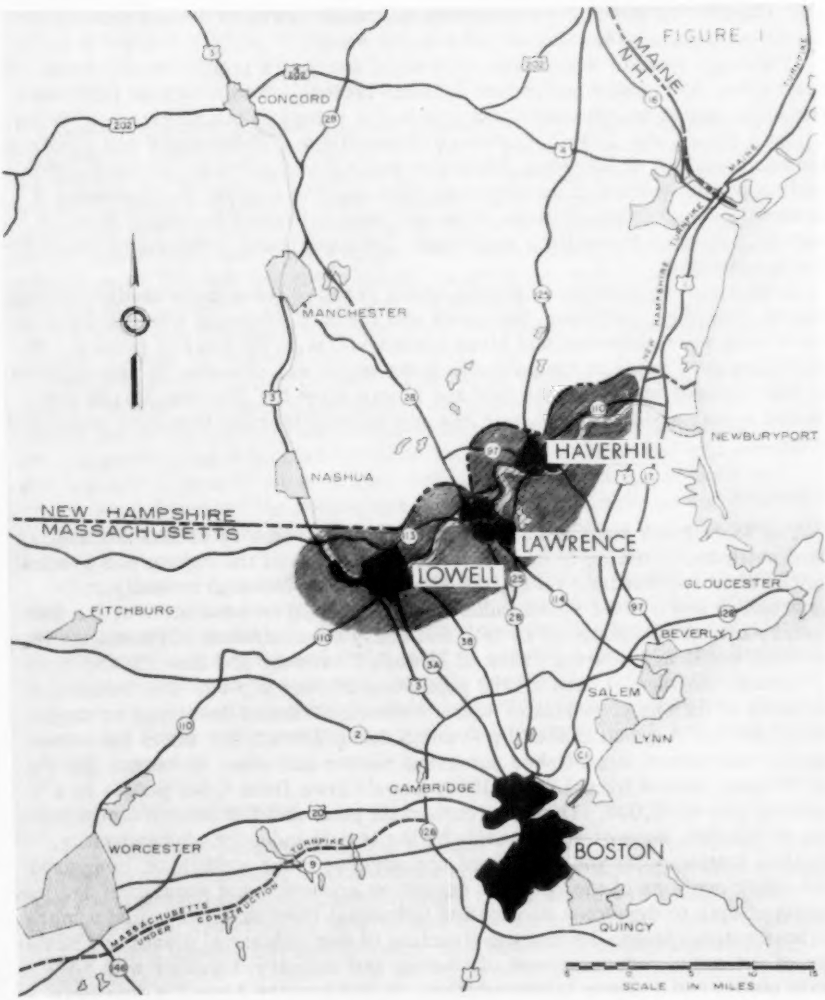
The Lowell, Lawrence and Haverhill region constitutes a satisfactory metropolitan unit for the development of a logical plan for regional highways which can be integrated with the overall highway program for the Commonwealth of Massachusetts and the nation. (Fig. 1) The three cities lie along the Merrimack River, 25 to 35 miles northwest and north from Boston. Each is an industrial city which reached the peak of its population and economic well-being in the 1920's. More recently, each of these important cities has lost population, largely because of decentralization movements into surrounding areas and industrial relocations to other regions.

The Master Plan

The master highway plan for this region comprehends 38 miles of Interstate Route 110 and connectors in addition to U.S. Highways 1 and 3 and Massachusetts Route 28. But the study comprehends much more than a plan for major highways. It presents a broad program of improvements needed to insure that the local street systems of the cities served by these state highways will have the capacities required to accommodate added traffic loadings which the new highways will bring to them in the future. The objective was to achieve a balanced capacity as between the main highways and the feeder and secondary system of roads and streets, which are an integral part of the whole pattern of highway transportation of the region. The survey also includes anticipated parking needs in these three cities.

Route 110, a major interstate highway to cost an estimated $90 million, was located not merely in terms of the shortest distance between terminal points and minimum cost for construction and right-of-way. The locations of this route and of the system of local feeder roads and streets were carefully adapted and adjusted to the present and future social needs and economic welfare both of the region and of its separate parts.

A large force of engineers spent the better part of a year in the field and office collecting and collating the information upon which the recommendations of this survey were based. Frequent meetings were held with, and the views, opinions and ideas collected from five mayors and city managers in the region and from the commissioners of public works, city engineers and planning officials. Housing authorities, chiefs of police and other civic bodies such as chambers of commerce were closely canvassed. All divisions of the State Department of Public Works contributed their extensive collection of information. The State Highway Department of nearby New Hampshire was consulted. All pertinent and available information in the Massachusetts Department of Commerce Divisions of Planning and of Statistics and Research was explored. Additionally, information and help were solicited from and freely given by the Boston and Maine Railroad, the Auto Club of Merrimack Valley, the New England Electrical System, the New England Telephone Company, the Municipal Gas companies and other utilities, which carry forward extensive and continuing studies of the communities they serve.



AREA LOCATION MAP

This is but a partial list of public, quasi-public and private agencies canvassed for information and ideas in relation to Interstate Route 110 and its feeder system of roads and city streets. In short, the engineers, statisticians and planners on this survey searched the minds and files of everyone who might contribute something of value to the study.

Thorough studies were made of present and future traffic requirements of the region, and of how the needed highway facilities would best be fitted into the hills, dales, marsh areas and across the rivers of the Merrimack Valley.

As a result, the Lowell-Lawrence-Haverhill survey develops and adapts a balanced pattern of freeways, highways and major streets to the future social and economic welfare of an extensive metropolitan region. It represents a desirable compromise between local and regional interests which, to some degree, are often in conflict, and traffic and topographic problems of substantial magnitude.

It may well be that the final plan which resulted from these studies did not please everyone. However, the views and ideas of everyone who had them to contribute were collected and given consideration in the overall picture. No objectors gave voice at the public hearing which was attended by approximately 100 regional and local officials and others when the plan was finally presented a year and a half ago, nor has any substantial objection been presented since.

Historical

The Merrimack Region was settled early in the history of Massachusetts, first settlements dating from 1633 to 1664. Growth of the region was gradual for the first two hundred years, its economy being based principally on agriculture and limited small industry. The industrial revolution of the 19th century brought phenomenal growth and heavy concentration of population in sections which are now the cities of Lowell, Lawrence and Haverhill.

Lowell, the largest, had a 1950 population of over 97,000. The initial stimulus of its industrialization was a network of canals developed in the early 1800's. A group headed by Francis Cabot Lowell, for whom the community was named, established numerous textile and other concerns. In the 70-year period from 1830 to 1900, Lowell grew from 6,500 people to a bustling city of 95,000. The city reached its peak about 1924 with a population of 113,000, supported primarily by the textile industry. Subsequently, obsolete textile mills and equipment and adverse labor conditions, compared with other sections of the country, caused an economic and population decline. Strong efforts to develop a diversified industrial base have prevented a more serious retrogession. Recent construction of new industrial plants and initiation of extensive redevelopment of housing and industry, together with adequate street and highway transportation, should restore Lowell's economic health.

Lawrence has a history similar to Lowell's. The Essex Company, formed in 1845, undertook the construction of a system of canals and a large number of the textile mills and other buildings. The city grew to a peak population of 94,000 in the early 1920's, but since has dropped to about 81,000. Active municipal and civic groups are undertaking the rejuvenation of Lawrence to place it on a firm and diversified industrial base.

Haverhill, founded in 1640, is the oldest and the smallest of the three cities. It differs from the other two in that shoe manufacturing is the largest

single industry, although textiles played an important part in its growth. Like the other two cities, Haverhill has suffered an economic decline in the past 30 years and is now making strong efforts to revitalize its industry and commerce. Population, which was at a peak of 54,000 in the 1920's, declined to about 47,000 by 1950.

Need for a Master Plan of Highways

Adequate and well-planned highway improvements relieve existing traffic congestions, provide for normal future traffic increases and encourage new movements of traffic. This last factor is particularly desirable in the Lowell-Lawrence-Haverhill area, which seeks to share in the economic prosperity now enjoyed in increasing measure by the rest of the Commonwealth and by the country as a whole. The three cities, with a combined population of 225,000, are the centers of a growing region with an overall population of 370,000. The economy and welfare of this region, its industry, communications, transportation and basic services, are dependent upon and come to a focus in these cities.

Effective rehabilitation of these cities must include a general improvement of facilities for automotive transportation and relief from intolerable traffic congestion on the highway and street system. Better arterial highways will encourage regional vehicular travel to and from the cities and will aid the development of nearby rural areas. Improved highways and streets within the cities will further the redevelopment of urban commercial and housing properties and enhance the value of the cities as business and shopping centers of the region.

Except during depression and war years, the rise in annual mileage of motor vehicle usage has so closely paralleled the advances of progress of national production that the interdependence of the two has been clearly demonstrated. Thus, the redevelopment of Lowell, Lawrence and Haverhill is keyed to a comprehensive and carefully coordinated system of highways and streets, adequate to accommodate, without stifling congestions, present and future traffic movements upon which the region's health and welfare so greatly depend.

Coordinating the Planning

The municipal governments, the housing authorities, the industrial redevelopment commissions, the chambers of commerce and other civil groups are working actively toward improvement of all aspects of these cities. Aided in some instances by federal and state agencies, this planning already has resulted in new low-rent housing, new industrial plants and other developments.

The highway and street program outlined in this study was planned to mesh with and enhance the improvements contemplated by these civic bodies. To that end, frequent meetings were held with officials responsible for these developments.

Regional Highway Planning

The regional highway and city street studies were carried on concurrently and were closely interrelated. For clarity, however, each of the two will be described separately.

Collection of Traffic Information

The initial step in the regional highway planning was the collection of information with regard to present traffic movements through the region. In 1954, the State Department of Public Works in conjunction with the Bureau of Public Roads conducted an origin and destination survey of traffic movements. Information was gathered by questioning drivers of passenger cars and commercial vehicles at carefully selected interviewing stations. Origin and destination data were collected on nearly 540,000 vehicular trips from driver interviews at 53 stations. In 1954 and 1955, the Department made hundreds of manual and automatic counts of traffic movements throughout the region and particularly within the centers of the three cities.

Traffic Desire Lines

Subsequently, the authors and their associates were engaged to process the voluminous traffic data and to develop what regional highway and city street improvements will be required to meet anticipated future traffic demands. The origin and destination survey data were analyzed to develop the lines and magnitudes of traffic desires. Lines of similar orientation were grouped into major desire lines (Fig. 2) with widths drawn to scale to represent volumes of traffic. As would be expected, the cities of Lowell, Lawrence and Haverhill are the focal points of highway movements within the region.

Accommodation of Traffic Desires

Comparison of the major desire lines with existing and previously planned arterial highways disclosed the traffic demands for which adequate facilities have not been anticipated or provided.

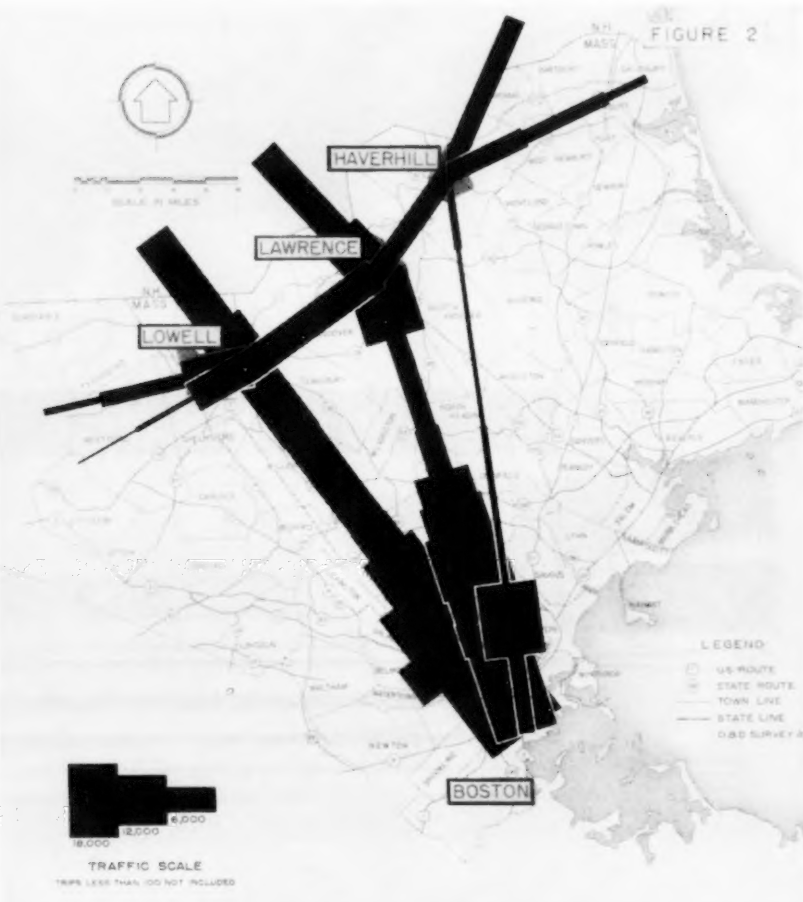
The desire line which extends southeast from Lowell toward the Boston Metropolitan Area is now served principally by Massachusetts Routes 3A and 38 and by U. S. Route 3, part of which is a new express highway. This improvement has been planned and is being executed by the Massachusetts Department of Public Works.

The composite north-south desire line running through Lawrence will be served by the new Route 28, which, as planned by the Department of Public Works, will extend from the Boston Metropolitan Area to the New Hampshire border as part of the interstate highway system. Various shorter routes which have been planned by the Department will serve other segments of the desire lines.

The composite desire lines for travel between Haverhill and the Boston area are too light to justify economically the construction of a new direct route. This traffic will be served adequately by existing and planned routes which also will serve other cities and towns.

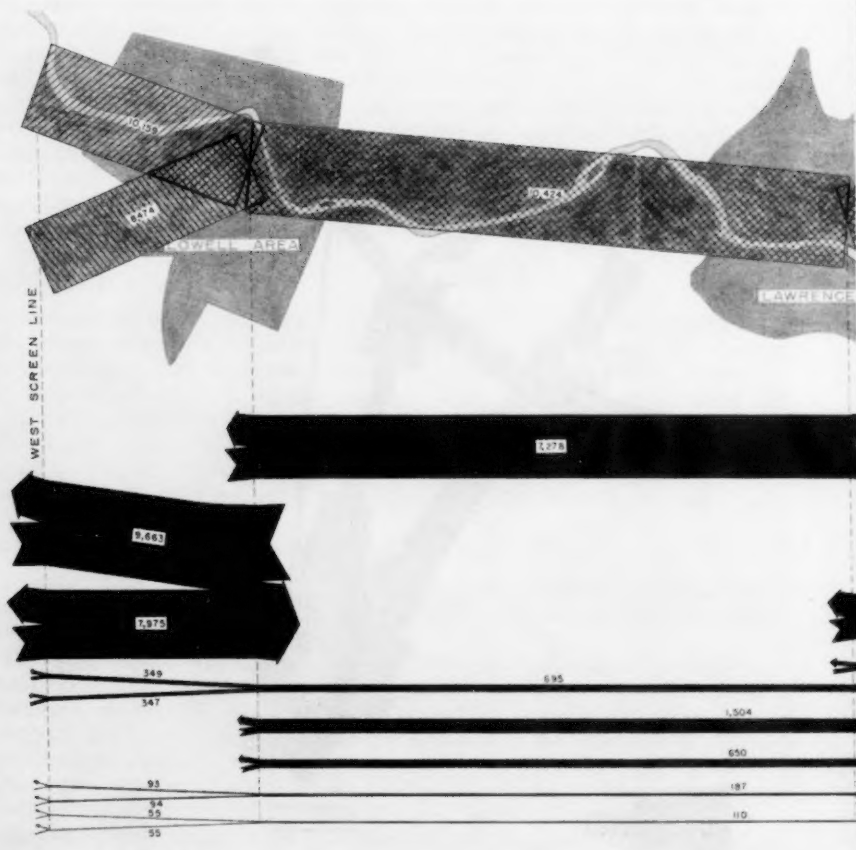
Desire Line Through Lowell-Lawrence-Haverhill

The principal, remaining regional flow of traffic shown by the composite desire lines extends on a northeast-southwest axis through Lowell, Lawrence and Haverhill. At present, this traffic is served by several land service roads all of which pass through the urban cores of the region. Judged in terms of modern standards of highway safety and capacity, these routes, which are moderately satisfactory in some rural sections, are wholly inadequate in the more congested urban areas. Planning for a new route along



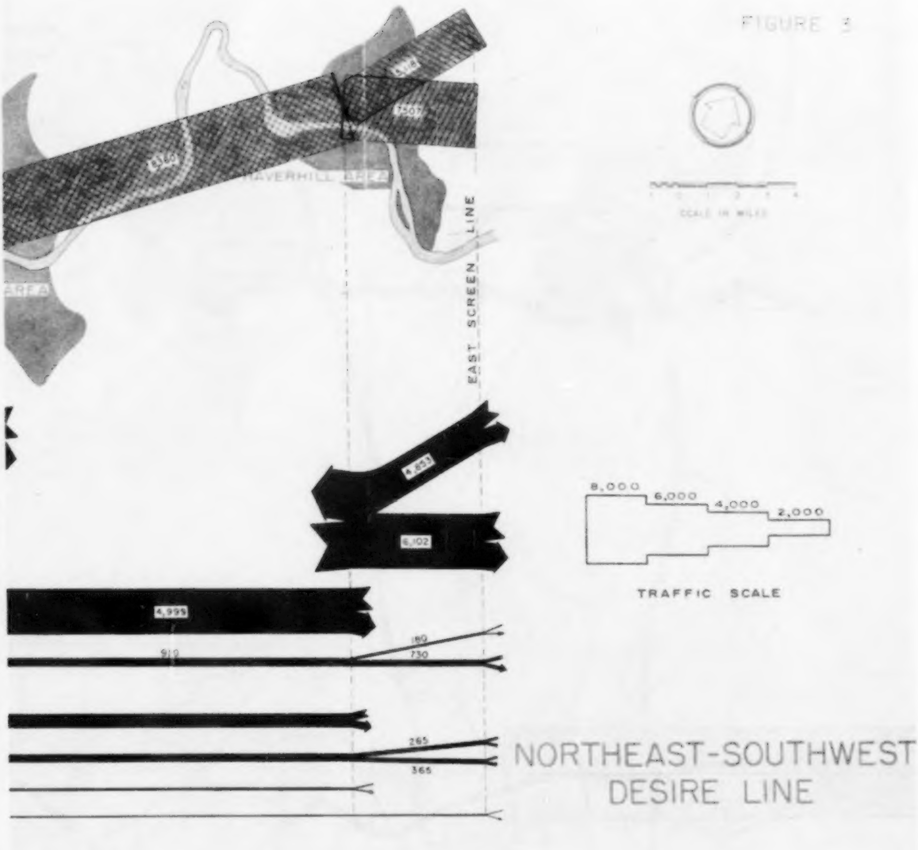
MAJOR DESIRE LINES

1954 AVERAGE WEEKDAY TRAFFIC - ALL MOTOR VEHICLES



this axis and its integration with other existing or proposed routes is the principal concern of the regional highway portion of these studies. For present convenience this route is referred to as Route 110 Freeway. It will probably be given a new interstate number at a later date.

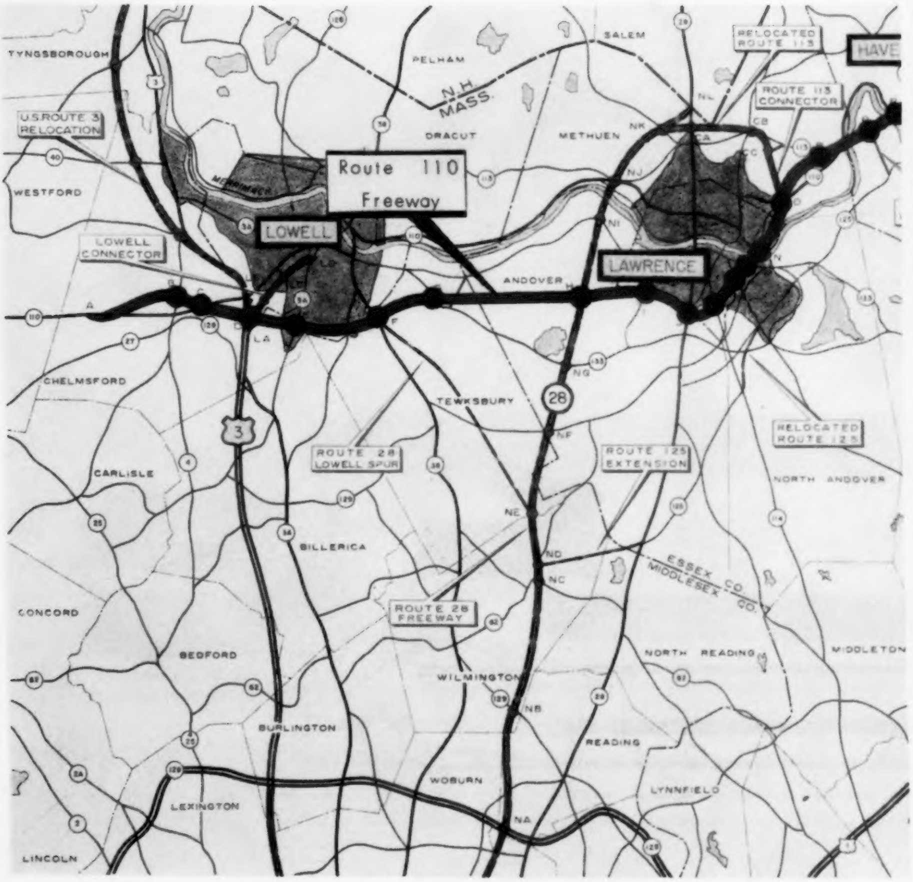
The composition of the traffic flows which make up this northeast-southwest desire line, (Fig. 3) has been broken down to show the volumes of traffic which travel between the cities, between each city and points beyond the limits of the area, and straight through the area without stopping. The breakdown shows that vehicles with origin or destination or both in one or more of the three cities represent the greater portion of the traffic. This analysis supports the conclusion that the planned regional highways should be oriented primarily to serve the short-haul traffic between and adjacent to the three cities in preference to the much lighter volumes of through traffic.



Locating Route 110 Freeway and Connectors

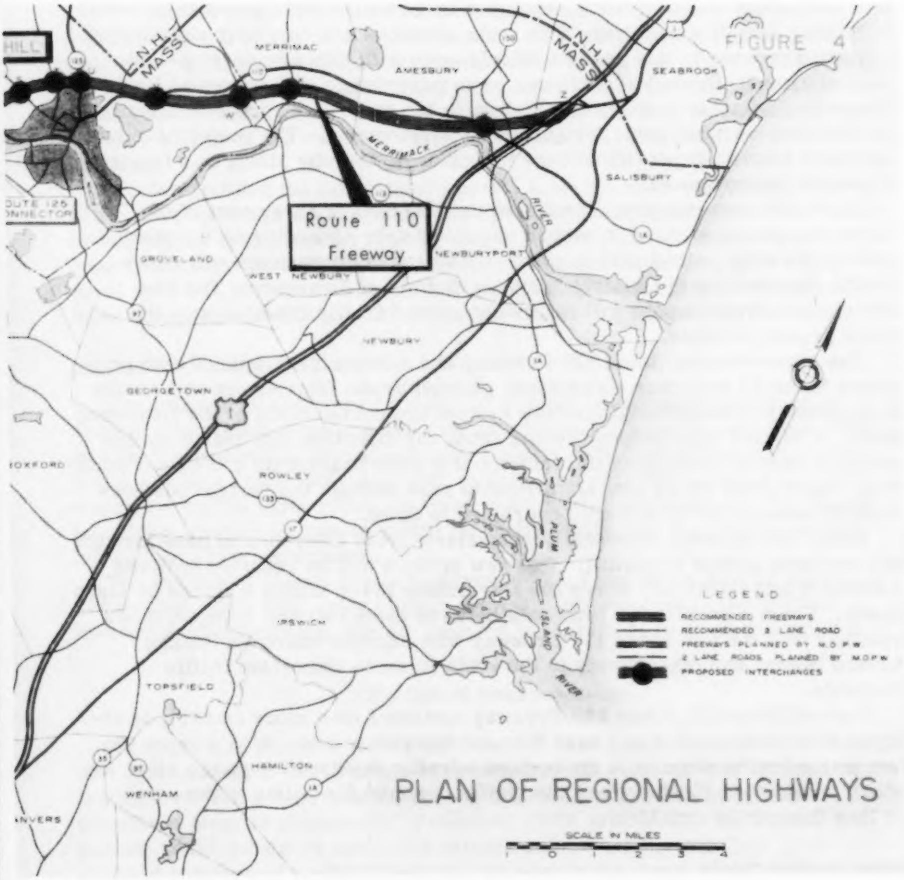
Location of recommended Route 110 Freeway and its connectors was based on consideration of greatest traffic service, topography, minimum disturbance of property and public utilities and reasonable costs. Aerial photographs and contour maps were the principal tools. The routes were located as closely as possible to the lines of principal traffic desire throughout the region, thus to satisfy demands for present and future traffic service. At the same time, the routes were located where the topography permits compliance with standards for modern express highway design and where connections can be made with elements of the local road and street system which are most suitable for traffic distribution.

Improved property was avoided wherever possible to minimize disruption of residential areas, business and industrial plants and to preserve tax



ratables. Plans of each community for future land use were carefully considered. Disturbance of public utility lines such as gas, water, sewerage and electric was avoided where possible. Consistent with the accommodation of present and future traffic demands and physical requirements, costs of construction and right-of-way were a major determinant in the selection of the recommended route locations.

A number of possible alternate locations for various sections of Route 110 Freeway and its connectors were investigated. Studies of those alternates which appeared most promising were carried through the full procedure of assigning traffic, estimating cost and examining topography and land use.



The Recommended Locations

The recommended Route 110 is planned as a completely controlled access freeway between Chelmsford and U.S. Route 1, (Fig. 4). A future extension of Route 110 Freeway southwesterly to the Worcester area with a connection to the Massachusetts Turnpike is contemplated. Subsequent to these studies, the entire route was designated an interstate highway.

Initially, the southwest terminus of Route 110 will be an interchange with existing Route 110 west of Chelmsford center. The new route will extend in a northeasterly direction passing south of the more densely populated center of Lowell. A new expressway spur connection, referred to as the Lowell Connector, will carry traffic into the center of the city from Route 110 and from Route 3, which runs south to the Boston area. This connector will join an improved system of streets near the center of the city.

The interchange between Route 110 and the Lowell Connector lies adjacent to a new industrial park being developed by an active civic group in an effort to bolster Lowell's economy. The route locations are carefully coordinated to provide access to and prevent interference with this new development. East of Lowell, Route 110 continues to an interchange with proposed Route 28 Freeway. Adjacent to these two routes, in the southwest corner of the city, an area has been set aside for industrial development. The routes have been carefully located to provide access to this area, thereby aiding this important economic improvement.

Route 110 makes a new crossing of the Merrimack River east of the Lawrence business district, and an improved spur connector on the north side of the river, along with various city street improvements will carry traffic destined for the central business district of Lawrence. The new Merrimack River Bridge will relieve congested traffic conditions on the three present bridges.

The recommended Route 110 Freeway and connectors combined with proposed Route 28 and other connections planned by the Department will create a complete circumferential freeway system around the heart of the Lawrence area. A vehicle approaching the city from any direction may travel on this circumferential route to an interchange at a point nearest its ultimate distination. Many trips which now are forced to pass through the central business district unnecessarily will no longer need to do so.

Route 110 Freeway proceeds northeasterly from Lawrence to pass through the northern part of Haverhill. Two new bridges will be required between Lawrence and Haverhill, where the Merrimack River makes a series of sharp bends. From a point in the peninsula between these two new bridges, a new roadway will connect Route 110 Freeway with express highways leading toward Boston and other points to the south to serve important traffic demands.

East of Haverhill, Route 110 Freeway continues on a more easterly bearing to a terminus at Route 1 near the new Hampshire line. It will serve the two major traffic desires in the section - traffic destined for points along the shore in and near Newburyport and traffic destined for points to the north in New Hampshire and Maine.

Lane Requirements

1954 and 1980 average weekday traffic volumes were assigned to the proposed regional highways. (Fig. 5) The 1954 volumes were assigned to six alternate route systems investigated in the process of determining the best location for recommended Route 110 Freeway and Connectors. Traffic volumes on the recommended route system were expanded to 1980 to provide a basis for determining the numbers of lanes required both now and in the future on the mainlines and for planning the traffic interchanges.

Traffic assigned to the various routes assumed the existence in 1954 of all proposed new and relocated routes and city streets in the study area. Each trip recorded in the origin and destination survey was considered individually and assigned to proposed routes in the proportion of probable use. The principal criterian for assignment was the relative travel time via the proposed routes and existing routes. Other criteria were travel distance, and to a limited extent, intangibles such as convenience and driver preference for expressway travel.

The 1954 assigned volumes served as a base for forecasts of volumes which could be expected in 1980, the terminal date of the study period. A separate growth factor was established for each survey zone on the basis of expected population and vehicular registration increases. Trips assigned to the routes were expanded individually in proportion to the anticipated growth of the two terminal zones. Induced traffic, that which will be generated by the desirability of the superior highway facilities, is included in the 1980 volumes.

For determining the lane requirements, a design hour was established at 15.5% of the average daily volume and the directional peak volume was taken as two-thirds of the two-directional design hour volume. Design hour capacities of the freeways were set at 1,000 vehicles per lane per hour in rural areas, 1,200 in suburban areas and 1,500 in urban areas. Numbers of lanes were allocated to provide sufficient capacity through the year 1980.

Stage Construction Program

The component sections of Route 110 Freeway and connectors have been arranged into a 14-stage construction program. Provisions have been made so that more urgently needed sections may be constructed first and so that there will be a reasonably equitable distribution of traffic service improvements among the three cities as stage construction progresses. The stages have been planned so that each will be usable in the interim before connecting sections are constructed.

The individual stages vary in estimated cost from about $2-1/2 million to $14 million. The total construction and right-of-way cost of the recommended arterial highway system covered in this study is about $90 million.

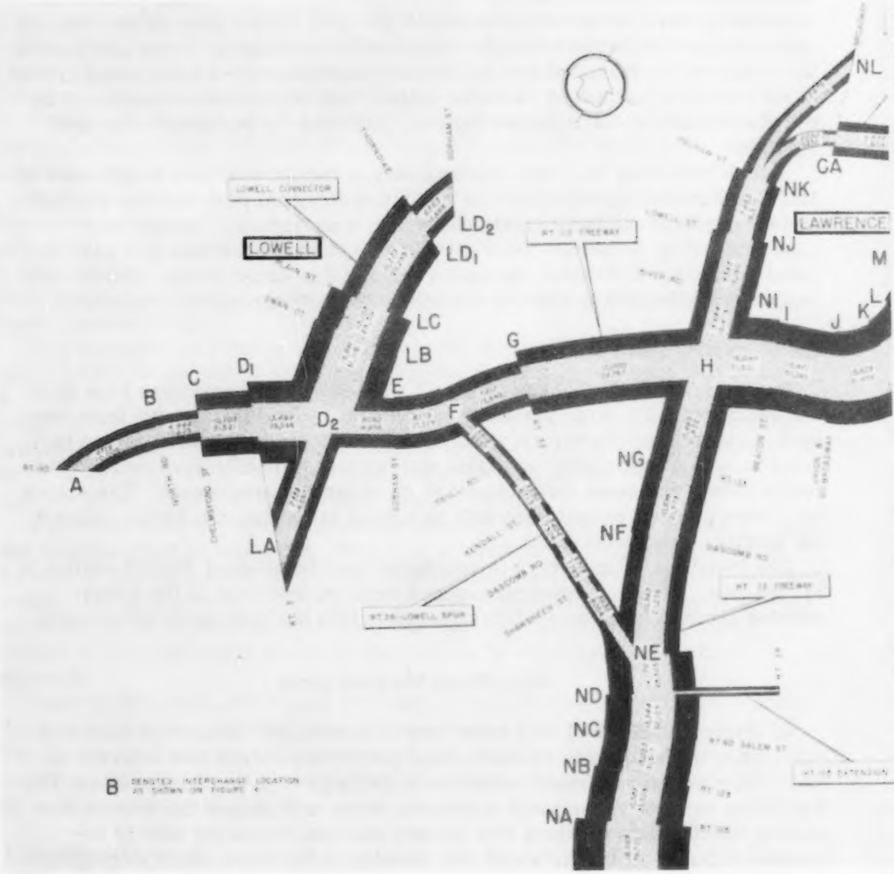
City Street Improvements

An important phase of this study was to investigate what steps should be undertaken in these three cities to anticipate new patterns and volumes of traffic flow which will result when the major highways are in operation. The objectives were to recommend measures which will reduce the severe congestion which exists on many city streets and insure smooth flow of increased volumes of traffic which will develop in the three cities during the next 25 years.

Traffic Studies

In the studies of needed city streets improvements, the initial step was an inventory and appraisal of present conditions in Lowell, Lawrence and Haverhill. The external origin and destination survey, together with an internal O and D obtained by interviewing parkers, were basic to this investigation. Each trip recorded in the surveys was considered individually and assigned to the most logical city street routing. The assigned volumes then were cross-checked with the traffic counts recorded on each street and adjusted accordingly.

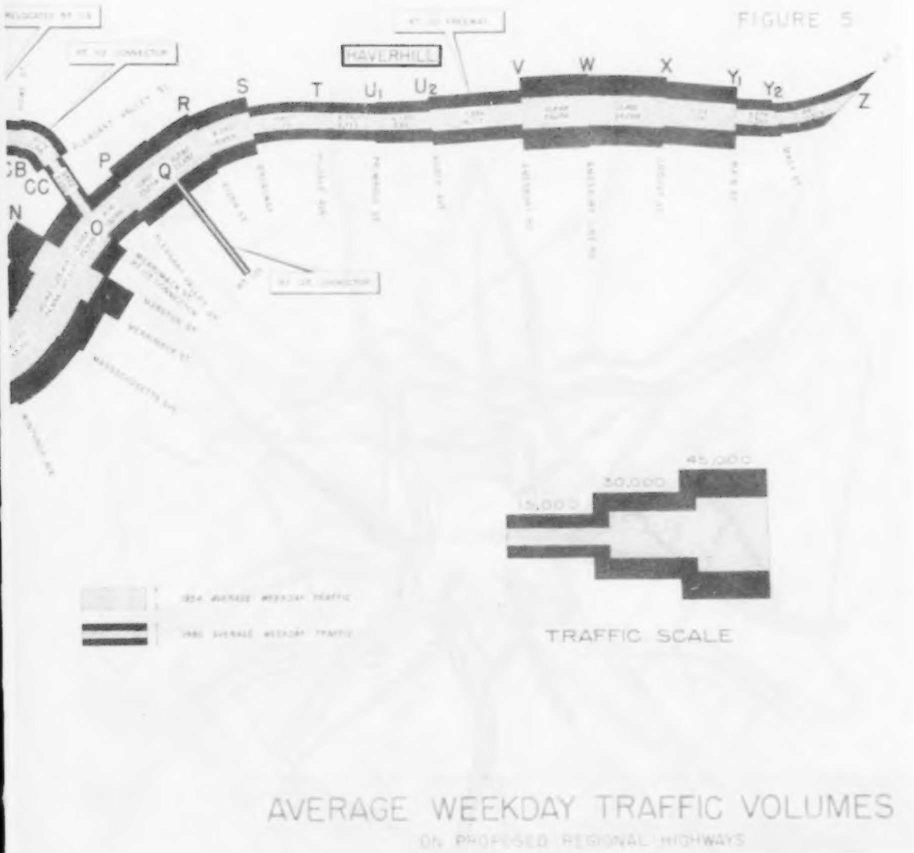
1954 average weekday traffic flow charts were developed for the streets in each of the cities, and separate details were prepared for the central business districts. The traffic flows in Lowell are illustrative of the conditions found in each of the cities (Fig. 6).



In addition, investigations were made of traffic flows which pass through the external cordon stations with no reference to which city streets are used. These flows are made up of vehicles which pass through the city without stopping and those which have origin or destination within the city. These investigations aided in determining the extent to which some traffic may be redistributed over less congested routes.

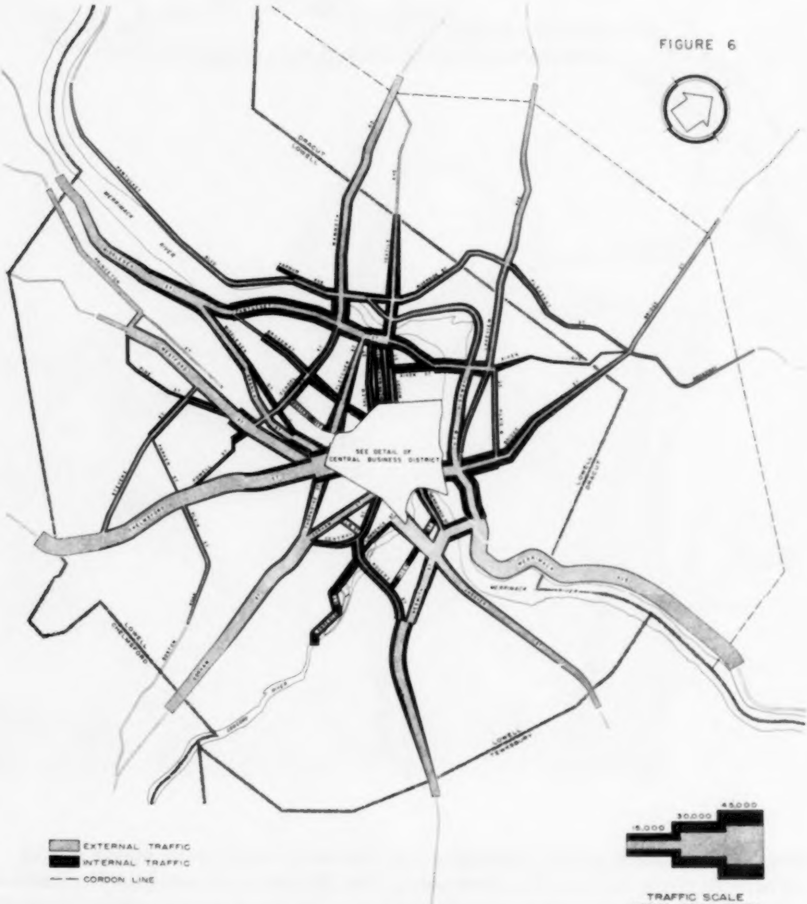
Further investigations were made of vehicular flows expected on the streets of the three cities in 1980 (Fig. 7). Estimates of future traffic volumes were made in the same way as were those on the regional highway system, each trip combination being expanded individually.

Traffic flows over city streets were determined first on the assumption that there will be no new regional highways or city street improvements. Then, assuming the planned regional highways and connectors to exist,

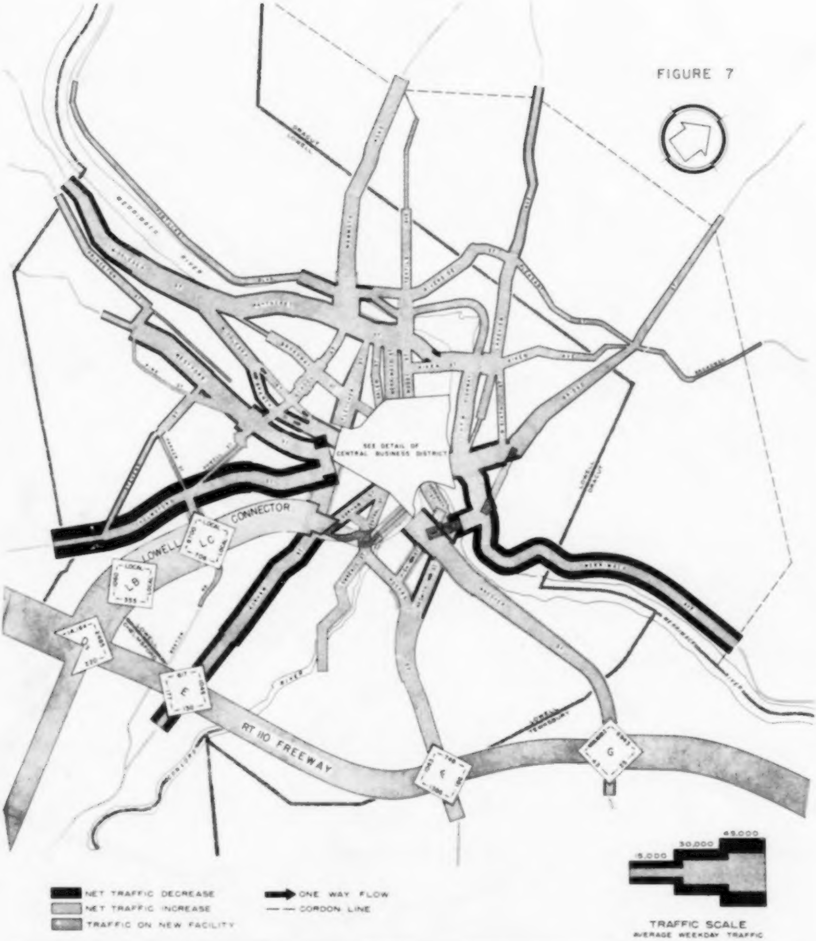


analysis was made of the changes in the traffic flows on each major city street. In many instances, it was found that the new regional highways and connectors will redistribute enough traffic to relieve present congestion on overloaded city streets, which will then be adequate for remaining traffic volumes. Conversely, flows on other city streets will be increased and provisions must be made to accommodate the greater traffic loadings.

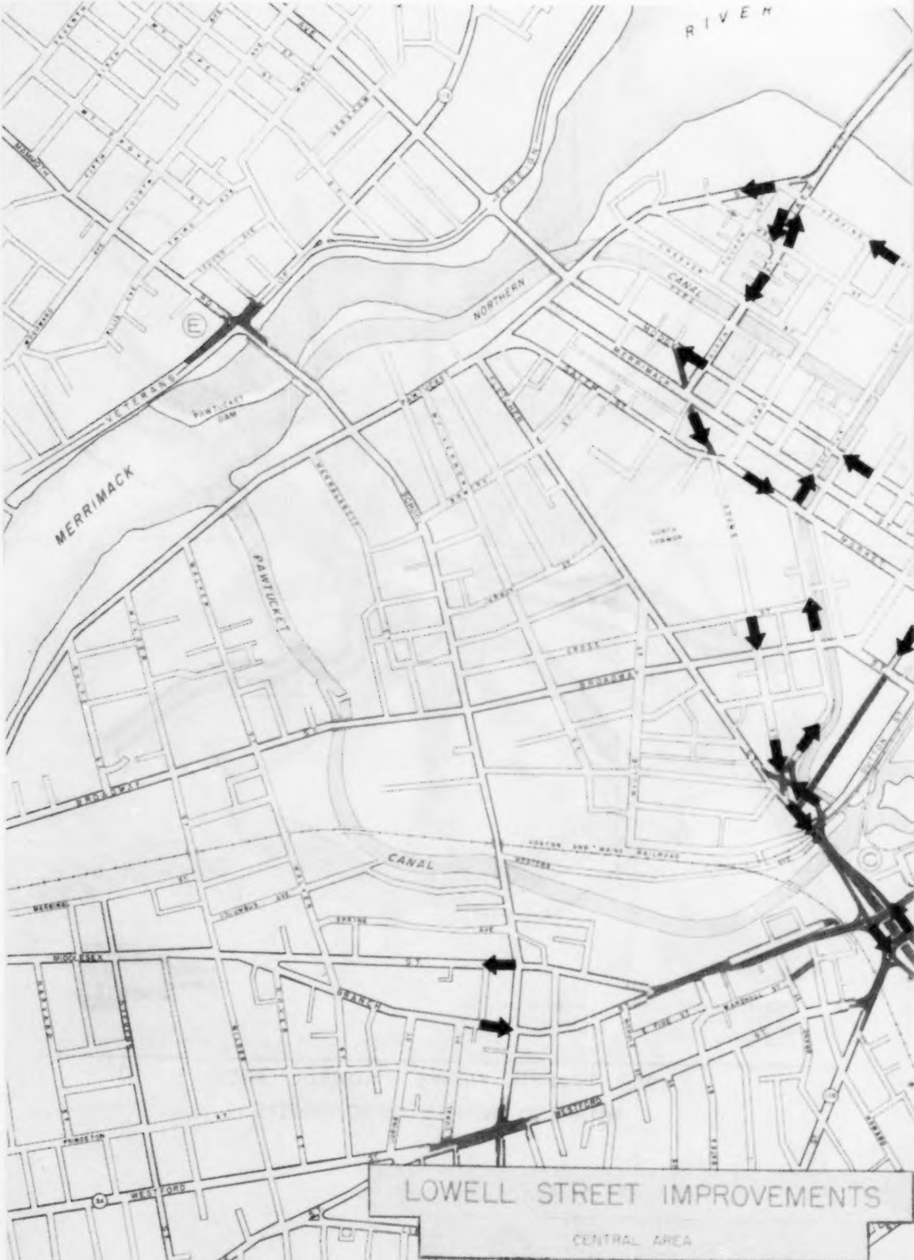
Consideration was also given to street traffic pattern changes and demands which may be expected to result from present and anticipated plans for housing, industrial and other significant land use developments in each of the three cities and in the areas surrounding them.



1954 TRAFFIC FLOWS - LOWELL AREA



1980 TRAFFIC FLOWS - LOWELL AREA
WITH AND WITHOUT IMPROVEMENTS


LOWELL STREET IMPROVEMENTS
CENTRAL AREA
RIVER
MERRIMACK
NORTHERN
CANAL
PAWTUCKET
CANAL
VETERANS
PAWTUCKET DAM
MERRIMACK
BROADWAY
MIDDLESEX
WESTFORD
BOSTON AND MAINE RAILROAD
MARKET
CROSS
SPRING
BRANCH
PRINCETON

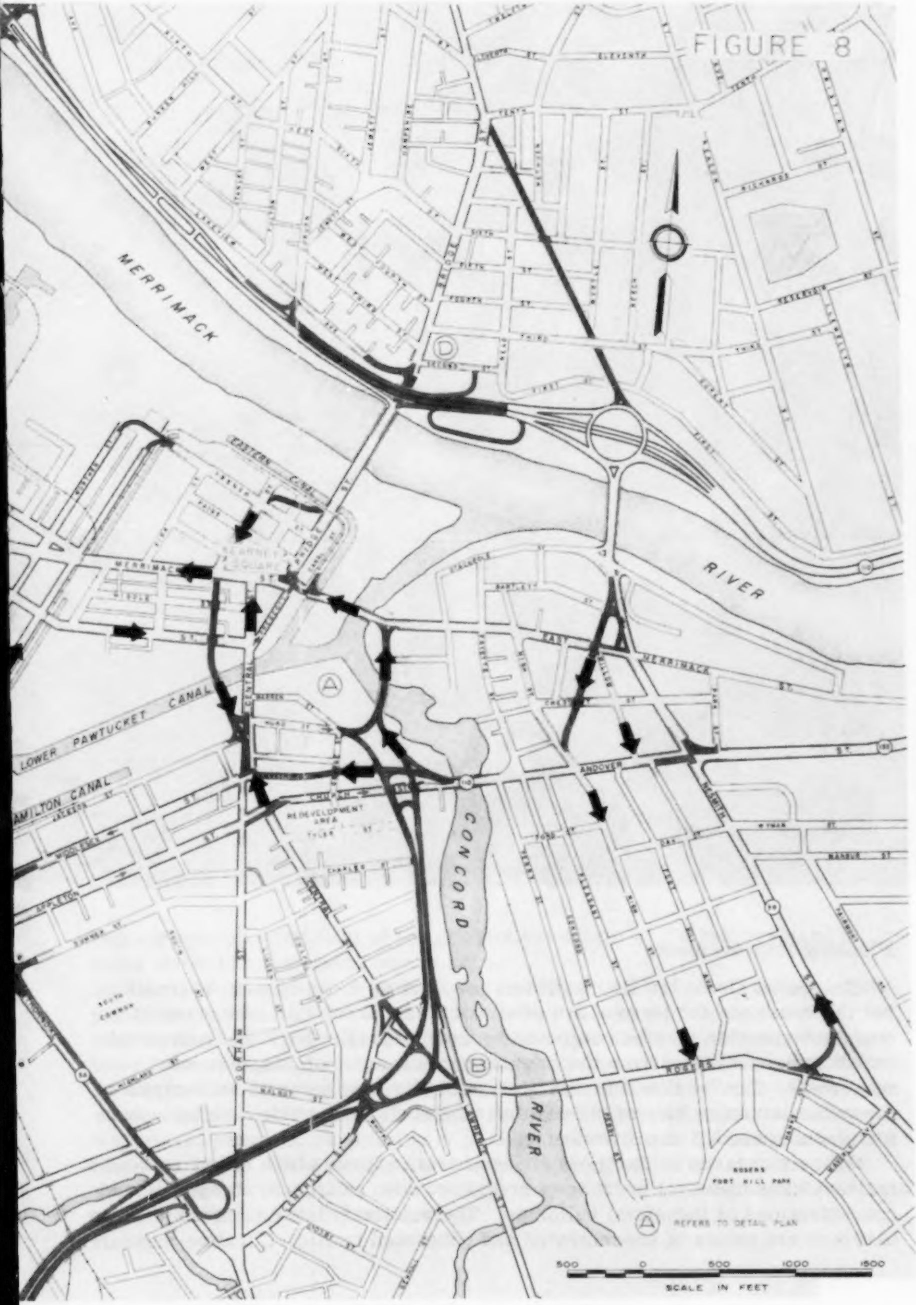
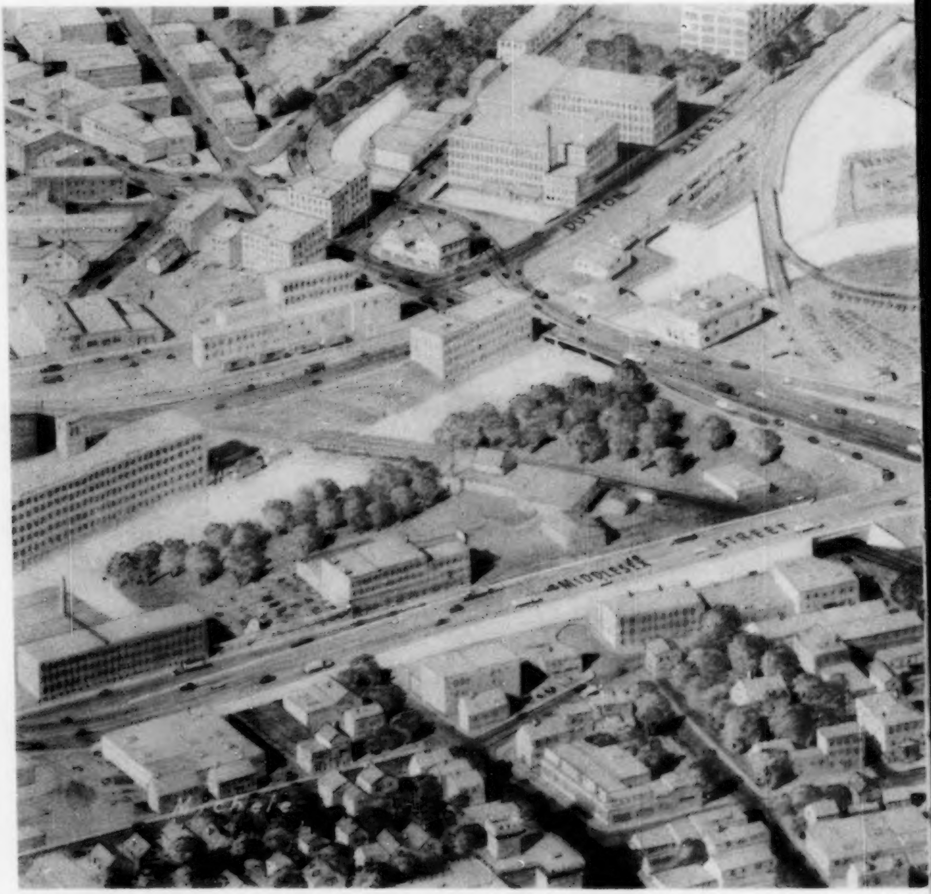


FIGURE 8
MERRIMACK
RIVER
CONCORD
RIVER
LOWER PAWTUCKET CANAL
HAMILTON CANAL
KEARNEY SQUARE
REDEVELOPMENT AREA
EASTERN CANAL
SOUTH COMMON
ROGERS FORT HILL PARK
REFERS TO DETAIL PLAN
500 0 500 1000 1500
SCALE IN FEET



Planning Improvements

Congested street traffic conditions are obvious from casual observations, but the causes of the tie-ups are often not so apparent. An otherwise adequate intersection may be congested because of traffic back-up from an adjacent intersection or from the interference caused by a single turning movement. Traffic flow and distribution charts together with an analysis of the vehicular capacities of streets and intersections provide a reliable base for planning needed improvements.

Notice was taken in the three cities of traffic flows which follow somewhat indirect lines of travel because of rivers, canals, railroads, steep hills and concentrations of industrial buildings. The relatively few crossings of these barriers are points of concentrated and congested traffic. Curative measures

require special treatment of the present crossings of the barriers and in, some instances, provision of new ones.

Partially as a result of these topographic barriers, Lowell and Haverhill, particularly, have irregular street patterns. These variations from a rectangular block plan cause difficulty where multi-corner street intersections, short blocks and non-continuous streets create inefficient traffic flows.

Corrective measures are often as simple as installation of traffic signals, channelization of intersecting traffic flows, creation and extension of one way street patterns, restriction of parking, or moderate widening of roadway pavements. In other instances more drastic revisions such as adjustment of offset streets and construction of new streets, grade separations and water crossings become necessary.

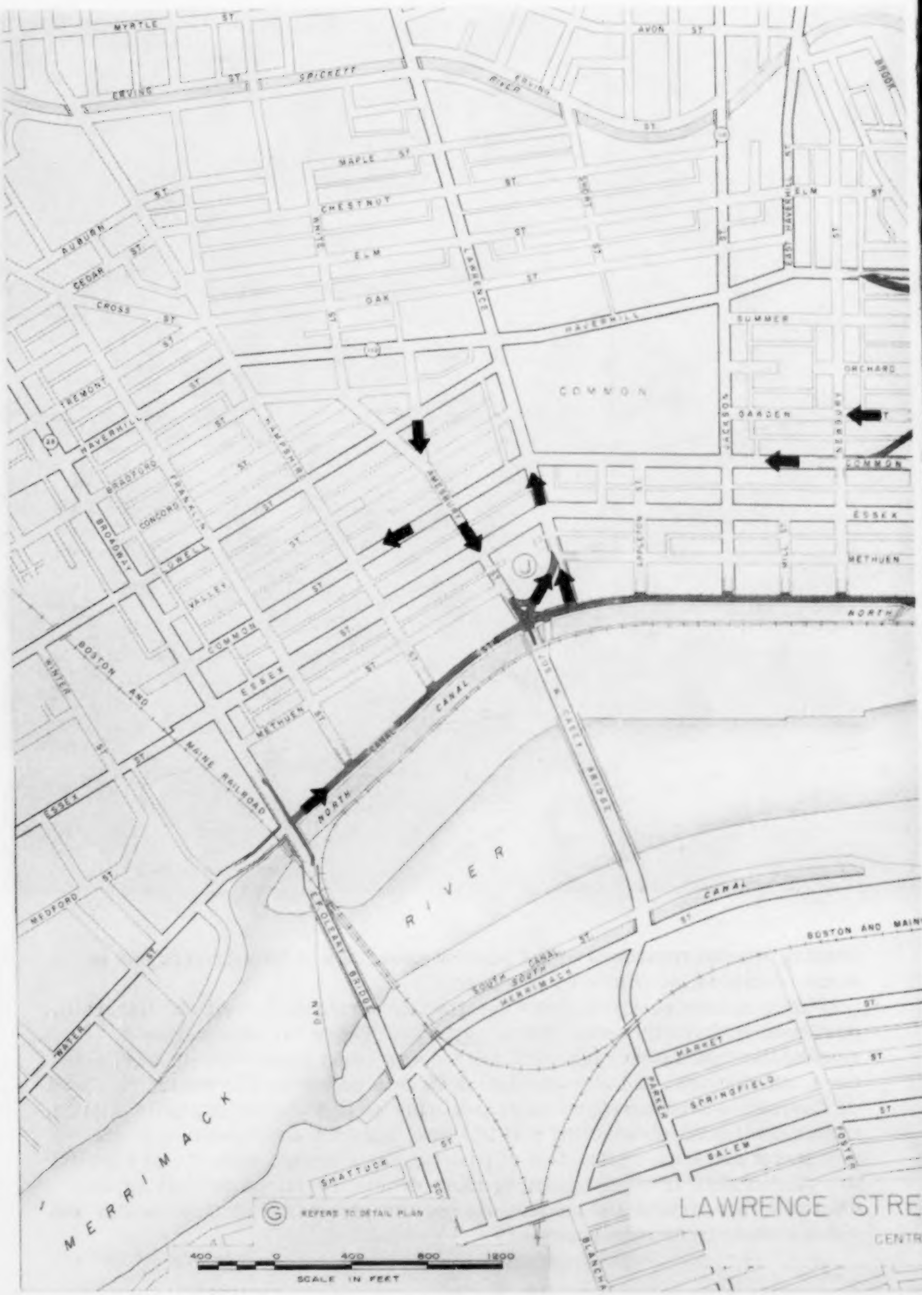

MYRTLE ST
SPICKETT
ERVING ST
SPICKETT RIVER
ERVING
AVON ST
BROOK
MAPLE ST
CHESTNUT
WHITE
ELM
OAK
LAWRENCE
SHORT ST
ELM ST
AUBURN ST
CEDAR ST
CROSS ST
TREMONT
HAVERHILL
SUMMER
COMMON
ORCHARD
GARDEN
JACKSON
NEWBURY
HAMPSHIRE
AMESBURY
BRADFORD
FRANKLIN
CONCORD
BROADWAY
LOWELL
VALLEY
COMMON
ESSEX
METHUEN
APPLETON
NORTH
BOSTON AND MAINE RAILROAD
WINTER
ESSEX
NORTH CANAL
JOE W. CASEY BRIDGE
RIVER
CANAL
BOSTON AND MAINE
SOUTH CANAL ST
SOUTH
MERRIMACK
MEDFORD
WATER ST
O'LEARY BRIDGE
DAM
MARKET
SPRINGFIELD
PARKER
SALEM
FOSTER
SHATTUCK
MERRIMACK
REFERS TO DETAIL PLAN
400 0 400 800 1200
SCALE IN FEET
LAWRENCE STREE
CENTRA
BLANCHA


FIGURE 10
MERRIMACK
RIVER
SPICKETT
RIVER
STORROW PARK
SHAWSHEEN
RIVER
PHILIP J. O'CONNELL PARK
MERRIMACK ST.
RAILROAD
MARKET ST.
GREENFIELD ST.
SALEM ST.
UNION ST.
MARBLEHEAD
MIDDLESEX ST.
INCINERATOR RD.
ALLSTON ST.
PLEASANT ST.
HOWARD
WOODLAND
HIGH ST.
CANAL
ISLAND ST.
BELMONT ST.
LAWRENCE
NORTH ANDOVER
IMPROVEMENTS

Lowell Improvements

The downtown section of Lowell, known as Kearney Square, has been troublesome for many years (Fig. 8). Although a one-way system already instituted has eased the problem, completely adequate accommodations for present and future traffic cannot be made within the limits of the present irregular street patterns. Insufficient crossings of the canals cause unnecessary traffic movements through Kearney Square.

Recommended improvements take the form of a one-way loop around the core of the city which will entail the construction of some new canal crossings and connecting streets. The principal arterial streets into the city such as the proposed Lowell Connector will feed into this loop for local distribution.

Other improvements will facilitate travel across the five Merrimack River bridges. Although the bridges themselves have adequate capacity for traffic flows, many of the intersections at the bridgeheads are deficient. Improvements will take the form of grade separations and, in some instances, channelization.

Another focal point of traffic congestion is in the vicinity of the Boston and Maine railroad station where vehicular congestion is aggravated by a grade intersection with the mainline railroad. Extensive reconstruction in this area including the grade separation of vehicular and railroad traffic will be necessary (Fig. 9).

Lawrence Improvements

On the whole, Lawrence has a more adequate street system than either of the other two cities because the streets were laid out when the city was established in 1848 on a more regular pattern (Fig. 10). However, Lawrence, too, has topographic barriers such as the Merrimack and other rivers, the railroads and the high land in the eastern part of the city. Points of traffic congestion are concentrated largely at these barriers.

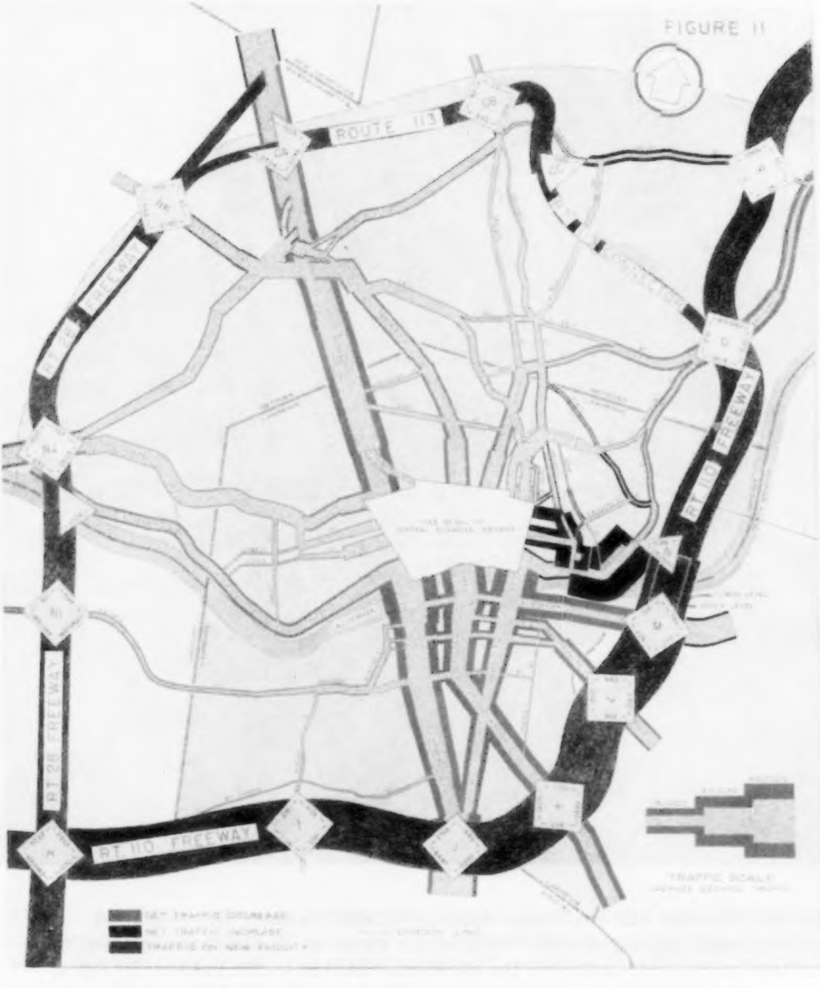
The principal city street improvements will be an improved connection between the central business district and Route 110 Freeway on the east, and the development of a one-way street pattern around the central business area. Through movements of non-stopping traffic need not traverse the main shopping center on Essex Street.

As in Lowell, improvements also will be made at the intersections adjacent to the present river crossings to allow for fuller use of the vehicular capacities of the bridges. Construction of the two new bridges in this area - Route 28 Bridge west of the city and Route 110 Bridge on the east side - will greatly reduce traffic burdens on the three existing bridges (Fig. 11). Through traffic, which has no business in the downtown area and which interferes with local circulation, will be almost entirely diverted to the new bridges. In addition, many vehicles with origin and destination in the central business district will find it advantageous to use the new crossings (Fig. 12).

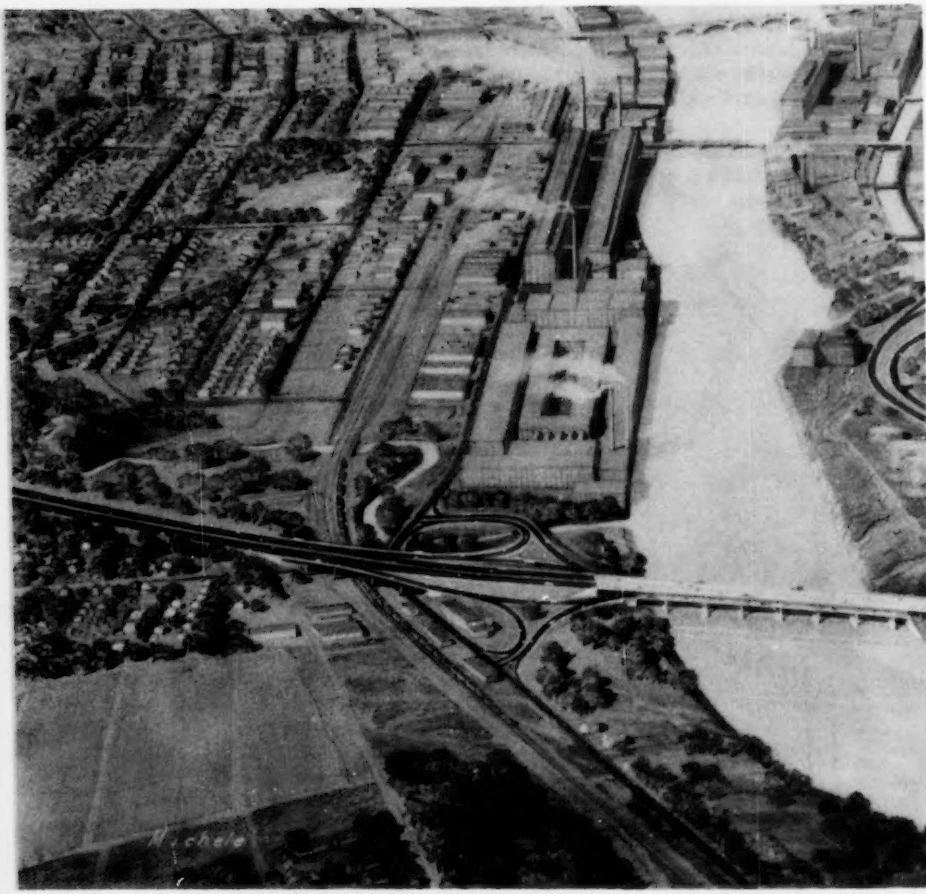
Haverhill Improvements

Irregularities in Haverhill's street pattern also are a reflection of the topographic barriers (Fig. 13).

With the relief afforded by Route 110 Freeway, the two present Merrimack River highway crossings will be adequate for future traffic demands to 1980.



1980 TRAFFIC FLOWS—LAWRENCE AREA



The new freeway will encourage external traffic to enter Haverhill via several radiating city streets north of the river as an alternate to using the existing bridges. In addition, the north approaches to the present bridges, which have less capacity than the bridges themselves, will need improvement to accommodate present and future traffic flows.

Other improvements will take the form of development of one-way street patterns on existing streets, using existing streets in combination with new, parallel roadways and construction of a new east-west and a new north-south street to divert unnecessary travel from the core of the city (Fig. 14).

Parking

The success of the regional highway and, particularly the recommended city street improvements in providing for present and anticipated future

traffic flows within Lowell, Lawrence and Haverhill will hinge upon provision of adequate parking facilities. Lack of a sufficient number of parking spaces causes drivers to "cruise" and double-park while waiting for spaces. These practices add to the traffic load and reduce the capacities of the streets. Resulting congestion tends to nullify the effectiveness of costly highway and street improvements and to discourage shoppers and others from visiting the central business districts.

Field Surveys

As an aid to the cities, the Department of Public Works, in conjunction with the Bureau of Public Roads, conducted extensive field surveys of parking in the central business districts of the three cities during 1954. As a cross-check on the interviewing, simultaneous counts were made of vehicles


BROADWAY
LOWELL AVE
ROCKLAND ST
LAFAYETTE ST
HILLDALE
BOSTON AND MAINS RAILROAD
LITTLE RIVER
MAPLE
STEWART
LANCASTER
HALE
WINTER
BLAISDELL
HILLSIDE ST
ESSEX
MARSHALL ST
BOSTON ST
HANCOCK ST
PILLING ST
OBSERVATORY
SILVER ST
HIGH
TEMPLE
CENTRAL
BEACON ST
WASHINGTON ST
GRANITE ST
B&M STATION
WASHINGTON
WILSON
BEACH ST
RIVER ST
MERRIMACK
SO. ELM ST
NEW HAMPSHIRE AVE
PROSPECT
FRONT ST
HAVERHILL STREE
CENTRA


FIGURE 13
T IMPROVEMENTS
AREA
LAKE SALTONSTALL
RIVER
MERRIMACK ST.
WATER ST.
SUMMER
ARLINGTON
ASHLAND
KENOZA AVE
HOWARD
FOUNTAIN
WEBSTER
MAIN ST
LOWER BRIDGE
CITY HALL
BOSTON AND MAINE RAILROAD
REFERS TO DETAIL PLAN
400 0 400 800 1200
SCALE IN FEET

entering and leaving the central business districts on principal streets. A total of 50,000 interviews were made in the three cities. In addition, an inventory was made of existing curb and off-street parking spaces in each central business district.

Visualization of Data

It was beyond the scope of the Master Plan of Highways to make full use of the extensive data collected in the parking surveys. That is a local function. As an aid to the responsible municipal officials, however, numerous visualizations were made of the survey data. Comparisons between parking demand, supply and usage were made for each group of blocks in the central business districts.

CONCLUSION

The effort in these studies has been to develop a balanced plan of highway and street improvements which will avoid the frequent mistake of solving some traffic problems only to create new ones. Roadway planning will not relieve traffic congestion and provide the ease of modern freeway and high-capacity street travel, however, unless it is followed by an actively executed design and construction program. The first elements of this regional highway plan are already in the final design stage with construction slated to begin sometime next year. Some of the city street improvements also have advanced to the design stage and other progress has been made in the inevitable process of selling the public on the desirability and the economic necessity of completing an integrated system of regional highways and city streets.

Paper 1651 May, 1958 HW 2

Journal of the
HIGHWAY DIVISION
Proceedings of the American Society of Civil Engineers

A NEW RUBBERIZED ASPHALT FOR ROADS

J. York Welborn[1] and John F. Babashak, Jr.[2]
(Proc. Paper 1651)

INTRODUCTION

Since 1930, a number of laboratory studies have been made showing that the properties of asphalts were altered by the addition of small amounts of natural rubber. Some of these changes indicated that the performance of road surfacing materials might be improved. Two natural rubber powders, known as Mealorub and Pulvatex, were the first special rubber additives developed primarily for use with asphaltic materials for road construction. Initially, they were added directly to asphalt-aggregate mixtures in the mixing plant. Later they were used by preblending the powder with asphalt and the rubberized asphalt used either in plant mixtures or as a binder for surface treatments. Since the development of these special rubber additives, a large number of experimental road surfaces have been constructed throughout the world.

During World War II a number of synthetic elastomers were developed and since then several of these also have been used as additives for asphaltic materials in road construction. Some were in the form of dry rubber powder, containing varying amounts of mineral fillers to keep the powder free-flowing and to improve dispersion of the rubber. Others were in the form of pellets and rubber compounds. The synthetic materials also were used mainly as additives to asphalt-aggregate mixtures in the mixing plant.

During the past few years there has been more interest in using rubber with asphaltic materials for surface treatments and seal coat construction. It has been observed that rubberized binders used in this type of construction were tougher, reduced the tendency of the surface to crack and bleed, and improved aggregate retention. In order to obtain the desired effect of the rubber on asphaltic materials for use in surface treatment construction, the rubber

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1. Director, Natural Rubber Bureau Road Research Laboratory, Arlington, Va.

2. Chemist, Natural Rubber Bureau Road Research Laboratory, Arlington, Va.

must be blended with the asphalt in some manner. This has led to a considerable amount of effort on the part of the rubber interests to develop special rubber additives and processes for rubberizing asphalts.

Present Methods used for Rubberizing Asphalts

To date, most of the asphalts rubberized with natural rubber have been prepared by adding the dry rubber powder to hot asphalt and blending the two with heat and agitation. Synthetic rubber additives in powder, crumb, or other forms have also been used to prepare rubberized binders. Until recent years there was very little work done to develop the use of either natural or synthetic latices as a means of rubberizing asphalt.

A number of experimental surface treatments were constructed in France using natural rubber latex in asphalt emulsions. In Australia and Malaya, road experiments were constructed in which latex was blended with hot asphalt with the aid of a silicone product to control foaming due to the water in the latex.

In 1953, J. R. Benson(1) developed a process to rubberize asphalt with latex. This process was licensed by the Husky Oil Company and during the past three years they have produced fairly large quantities of rubberized asphalt. Although various types of latex can be used with the Benson process, Husky Oil Company selected a styrene-butadiene type as most suitable to produce the desired characteristics when added to their asphalt.(2)

The Firestone Tire & Rubber Company(3) developed the use of a synthetic latex for direct addition to asphaltic mixtures during plant mixing, or for use in surface treatments by applying to the road surface during the application of hot asphalt through a separate spray bar on the distributor. Rubberizing was obtained by evaporation of the water in the latex when coming in contact with the hot asphalt.

The use of elastomers in latex form for rubberizing asphalt appears to have some advantage over elastomers in dry powder form. In order to obtain a free-flowing powder it is usually necessary either to partially vulcanize the rubber or to combine the rubber with an appreciable amount of inert matter. Pre-vulcanization of the rubber reduces its activity when added to asphalt, requiring high temperatures and long periods of heating to produce a good dispersion of the rubber in the asphalt. If large amounts of mineral fillers are used in the powders they often present the problem of settlement when preblended with asphalt, resulting in contamination of tanks and lines or clogging of spray nozzles on a distributor.

At present, dry powders made from natural rubber are imported for use here. Since natural rubber latex is a commercial product stocked in the United States its ready availability for use in rubberizing asphalt would be an advantage. The use of rubber in latex form also should have some economic advantage in that it would eliminate the added cost of converting latex into a rubber powder.

Some early work indicated that natural rubber in latex form would be more effective for rubberizing asphalts than the same amount of dry rubber powders.

Objectives of Study

Because of the potential advantages of using natural rubber latex for

rubberizing asphalts, the Natural Rubber Bureau Research Laboratory in 1957 started the investigation reported here.

Based on prior experience gained during blending of dry forms of natural rubber and by the other rubber interests using latex, certain fundamental objectives had to be considered in the development of a satisfactory rubberized asphalt:

1. The rubber additive used should be effective in changing the properties of the asphalt. These changes should be such as to reflect in improved performance of the binder.
2. The rubber should be uniformly dispersed in the asphalt to produce a composition that is homogeneous. There should be no separation of the rubber from the asphalt when the composition is stored under typical conditions used for asphaltic products. If mineral fillers are used with the rubber, as in dry rubber powders, they should be of the type and amount that will remain in suspension in the rubberized asphalt during storage.
3. The flow properties of the asphalt should not be affected by the rubber to an extent that normal construction practice would have to be greatly altered.
4. In the manufacture of a rubberized asphalt the rubber should be of a type that would disperse rapidly without resorting to excessive temperatures or time of heating to produce a product with the above characteristics.

Attempts were first made to prepare a rubberized asphalt by adding the latex to a hot asphalt with continuous stirring and heating for various periods of time at different temperatures. It was found that high temperatures and long periods of heating were required to produce blends that would not separate on storage, and even then the material was not entirely homogeneous. While the rubberized asphalts were extremely elastic, they did not have certain desirable low-temperature characteristics and the viscosity of the asphalt was increased to such an extent as to affect the normal use of the asphalt in plant mixing and application by a distributor.

During the addition of latex to hot asphalt it was noticed that there was an immediate flashing off of the water, accompanied by a coagulation of the rubber particles in the latex. This no doubt accounted for the longer period of heating required to disperse the rubber to a degree that would be stable on storage.

Various methods of blending were then tried in the laboratory to improve the dispersion of the rubber. It was found that by accelerating the rate of dispersion of the latex during the time it was added to the hot asphalt the amount of heating could be reduced. However, even though some of the blends were stable, they were still very viscous at high temperatures, with little or no improvement in low-temperature properties.

Since it has been common practice in the manufacture of rubber goods to add specific compounding materials to the rubber in order to produce a finished article having the desired properties, it was reasonable to assume that additives also might be used with natural rubber latex to improve the properties of a rubberized asphalt. The additive needed was one that would reduce the time and temperature of blending required to obtain a storage stable material, increase low-temperature characteristics, increase the elastic and tensile properties, and have viscosity characteristics at high

temperatures similar to the unrubberized asphalt.

Initially, a number of commercial rubber additives, such as vulcanizing agents and accelerators, were tried. Although some of these resulted in improved dispersion of the rubber in the asphalt to the extent that the blend was stable in storage, they did not improve certain other physical properties. Of all the additives tried, the addition of small quantities of sulfur to the latex was found to have the most effect in improving both the blending conditions and the properties of the rubberized asphalt. Therefore, this report deals primarily with the effect of using sulfur with natural rubber latex on the processing and the physical properties of the resulting rubberized asphalts.

Preparation of Rubberized Asphalts

To prepare the blends, 300 grams of asphalt were weighed into a 600 ml. beaker and heated in a constant temperature oil bath at $340^{\circ} \pm 5^{\circ}$ F. An amount of latex to give the desired percentage of total solids was added to the asphalt during continuous stirring with a small electric laboratory stirrer at a speed of 1200 to 1500 rpm.

Experience had shown that latex containing approximately 62 per cent total solids could be added in about 0.5 per cent increments without causing excessive foaming due to water in the latex. For blends containing 1, 2, and 3 per cent rubber the total amount of latex could be added in about 3, 5, and 7 minutes respectively. Latices containing higher solid contents were diluted with distilled water to facilitate dispersion in the asphalt.

At the beginning of this study flowers of sulfur was used as an additive to the latex. Later a dispersed sulfur of the type used commercially for compounding with rubber latex was used. There was little or no difference in the properties of rubberized bitumens prepared with the sublimed (flowers) sulfur and the dispersed sulfur. The dispersed sulfur contains 73 per cent solids dispersed in water and can be easily mixed with latex. All of the results included in this report are on blends prepared with dispersed sulfur.

Sulfur was added to the latex in the amounts of 5, 10, 15, and 20 per cent of the total solids in the latex immediately before adding to the asphalt. With blends containing 1, 2, and 3 per cent rubber these amounts of sulfur based on the asphalt varied between 0.05 and 0.60 per cent.

Tests Selected for Evaluation of Rubberized Asphalts

Previous investigations have used a number of tests to evaluate the effects of rubber on asphalts. Standard asphalt tests such as penetration, softening point, viscosity, ductility, etc., were used by some while others adapted or developed special tests to show the effect of the rubber. Regardless of the tests employed the many investigations were able to show certain effects of combining various amounts of different types of rubber with asphalt. Some of the properties measured were changed only slightly while others were greatly affected by small amounts of rubber.

In this study, a number of tests were investigated for evaluating the effect of rubber on asphalt and the following were selected as the most useful to give the desired information:

<u>Penetration Test</u>, A.S.T.M. method D 5.

Softening Point Test, A.S.T.M. method D 36.

Ductility Test at 39.2° F., 5 cm. per minute, made in accordance with A.S.T.M. method D 113, except that a rate of pull of 5 cm. per minute was used at the test temperature of 39.2° F.

Toughness and Tenacity Tests, based on a method of test developed by J. R. Benson. A Scott Tester Model L-3 with appropriate testing heads and clamps was used. A detailed method of test used is given in the Appendix.

Storage Stability, tests to measure the storage characteristics of rubberized asphalts, made in accordance with a procedure developed in the laboratory. Details of the method are given in the Appendix.

In this study two standard types of natural rubber latex were used, differing mainly as to their method of production:

Latex A—natural latex concentrated by evaporation, containing approximately 73 per cent solids and stabilized with potassium hydroxide. (This latex was diluted to 64 per cent solids prior to blending with an asphalt.)

Latex B—natural latex concentrated by centrifuging, containing approximately 62 per cent solids and stabilized with ammonia.

Most of the detailed study was made using a Venezuelan asphalt; however, results are included showing the effect of this method of incorporating rubber on asphalts from other sources.

Table 1 gives the results of tests on rubberized asphalts using various amounts of natural rubber latices A and B without sulfur and with different amounts of sulfur. All the results reported here are for 300 gram blends heated for 1.5 hours at 340° ± 5° F. with high-speed stirring. Sulfur in the amounts of 5, 10, 15, and 20 per cent of the rubber was added to the latex prior to blending.

The softening point tests were made on small quantities of material removed at the 0.5, 1.0, and 1.5 hour periods to show the changes during blending. All other tests were made on the material after the 1.5 hour period. Results of tests on the original asphalt and the asphalt after heating for 1.5 hours at 340° F. are also given.

The drop in penetration of the asphalt without rubber during the heating and stirring seems quite large. However, much of this can be attributed to the effect of the high-speed stirring at the temperature of 340° F. The low viscosity of the asphalt without rubber caused some incorporation of air which in turn hardened the asphalt. A similar treatment on larger quantities of asphalt did not harden them to the extent shown for these small samples.

Small Amount of Sulfur Aids Blending

The effect of using various amounts of sulfur on the properties of asphalts rubberized with latices A and B is clearly shown in Fig. 1. Here the percentage of sulfur added to the latex for the 2 per cent rubber blends is plotted against the penetration, softening point, ductility at 39.2° F. and the toughness of the rubberized asphalt.

Compared to the blends prepared with 2 per cent latex without sulfur, the addition of sulfur to the latex during blending caused a decrease in softening point and an increase in penetration. The greatest changes produced by sulfur were in ductility and in toughness and tenacity. Blends containing latices A and B without sulfur had ductilities of 13 cm, while the addition of 10 per cent

Table 1. Results of tests on rubberized asphalts prepared from natural rubber latices A and B with various amounts of sulfur

Iden. Latex Blend No.	Rubber 1/ %	Sulfur 2/ %	Softening point after blending for 0.5 hr. °F.	1.0 hr. °F.	1.5 hr. °F.	Penetration 77°F.	Ductility 5 cm/min. 39.2°F. cm	Storage Stability 3/	Toughness in. lbs.	Tenacity in. lbs.	Elongation in.
Orig.	0	0	-	-	110	138	23	-	10	2	6
Heated 4/	0	0	-	-	112	110	19	-	10	1	5
A 1	1	0	117	118	119	98	13	2	26	12	20
A 2	1	5	115	116	115	110	67	1	25	14	23
A 3	1	10	116	113	112	117	89	1	30	21	30+
A 4	1	15	117	114	114	118	137	1	38	30	30+
A 5	1	20	118	114	114	115	91	1	49	39	30+
A 6	2	0	125	127	127	92	13	3	43	25	15
A 7	2	5	124	122	121	106	50	1	36	25	30+
A 8	2	10	131	122	118	104	145	1	68	57	30+
A 9	2	15	160	124	120	105	94	1	109	97	30+
A10	2	20	173	123	119	107	95	1	130	118	28
A11	3	0	135	134	135	82	12	3	60	39	14
A12	3	5	136	132	130	96	31	3	67	47	30+
A13	3	10	166	132	128	96	99	1	88	70	28
A14	3	15	210	137	128	97	70	1	150	135	30+
A15	3	20	168	170	182	97	55	2	93	76	12
B 1	1	0	116	116	118	105	18	1	18	5	15
B 2	1	5	118	115	114	110	65	1	31	17	30+
B 3	1	10	118	115	114	113	87	1	40	29	30+
B 4	1	15	117	113	113	114	150+	1	34	24	30+
B 5	1	20	118	113	113	115	77	1	43	34	30+
B 6	2	0	124	124	126	98	13	3	33	17	13
B 7	2	5	124	121	120	104	50	1	32	18	30+
B 8	2	10	125	122	119	105	141	1	82	68	30+
B 9	2	15	124	120	117	109	102	1	96	85	30+
B10	2	20	150	120	118	109	72	1	99	86	21
B11	3	0	133	136	137	83	13	3	54	35	10
B12	3	5	136	129	125	95	43	1	59	31	30+
B13	3	10	139	127	121	100	144	1	77	64	30+
B14	3	15	182	129	122	102	81	1	147	133	30+
B15	3	20	197	141	127	98	68	1	120	104	21

1/ per cent rubber, total solids from latex
2/ based on per cent of rubber
3/ storage stability; designations: 1) stable; 2) stable but granular; 3) unstable
4/ original asphalt after heating 1.5 hours at 340°F.

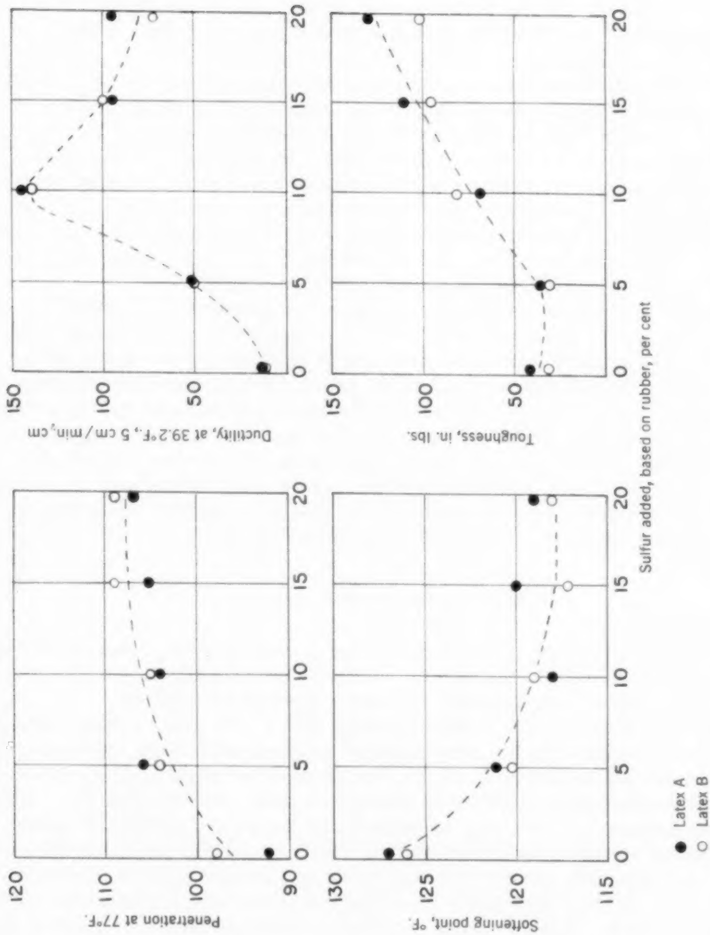


Figure 1. Effect of various amounts of sulfur on properties of rubberized asphalts containing 2 per cent rubber

sulfur increased the ductilities to 145 and 141 cm respectively. The toughness of blends containing latex A was increased from 43 to 68, and latex B from 33 to 82, by adding 10 per cent sulfur to the rubber during blending. The sulfur also increased the tenacity from 25 to 57 for latex A and from 17 to 68 for latex B.

In Fig. 2 the effect of the amount of rubber on the softening point, penetration, ductility and toughness are shown for blends with and without sulfur. The results plotted for the blends prepared with sulfur are those for the percentage of sulfur that gave the greatest increase in ductility. In the 1 per cent rubber blend this occurred with 15 per cent sulfur and for the 2 and 3 per cent rubber blends the maximum ductility was with 10 per cent sulfur, based on the rubber content. Fig. 2 shows further the large effect of using small amounts of sulfur with the latex on the properties of rubberized asphalt.

It should also be noted that by using sulfur the storage stability of the rubberized asphalts was improved. All blends made without sulfur were unstable except one, containing 1 per cent rubber and this appeared granular. In contrast, all the blends prepared with sulfur were stable with the exception of blend A 12 containing 3 per cent rubber and 5 per cent sulfur. By increasing the sulfur to 10 per cent this blend was also stable.

During the toughness test many of the blends prepared with sulfur elongated the full capacity of the tensile tester and are reported as 30+ inches. As shown in Fig. 3, there was little decrease in the load curve for the entire elongation or the tenacity portion of the curve. The elongations reported as less than 30 inches indicate either that the material broke or that it reached a point of zero stress. Although the asphalt without rubber would elongate the full 30 inches, the values reported are the elongation to the point of zero load.

The threads formed during elongation in both the ductility and toughness tests had much greater cross-sections for the latex-sulfur blends than for asphalt without rubber. This is illustrated in Figs. 4 and 5.

Effect of Dry Rubber Additives

As mentioned earlier in this report, two natural rubber powders have been used quite extensively in the past as additives for asphaltic plant mixtures and also for rubberizing asphalts for use in surface treatments.

In order to compare the effects of using sulfur with these rubber additives, blends were prepared in the same manner as those with latex, containing 2.0 per cent total solids and 0, 5, 10, 15, and 20 per cent sulfur. The results of tests on these blends are shown in Table 2 together with the results of tests on blends containing 2 per cent of latex A and the same amounts of sulfur.

The effect of sulfur on the ductility at 39.2° F. and the toughness of the blends containing the two ruber powders and the rubber from the latex are shown in Fig. 6. For Mealorub, the sulfur increased the ductility and toughness only slightly. A fairly large increase in these properties occurred with the sulfur added to Pulvatex but this increase was considerably less than for the blends prepared from latex A.

Effect of Other Elastomers Studied

In order to compare the properties of asphalts rubberized with synthetic rubber, blends were made by adding synthetic latex to hot asphalt following

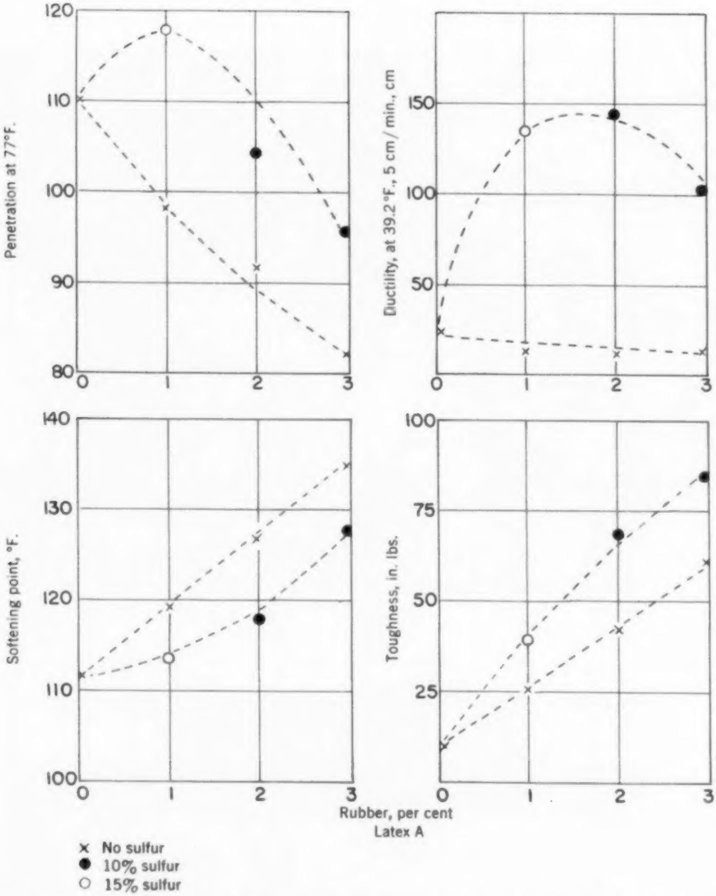


Fig. 2 - Effect of rubber content on properties of rubberized asphalts prepared with and without sulfur

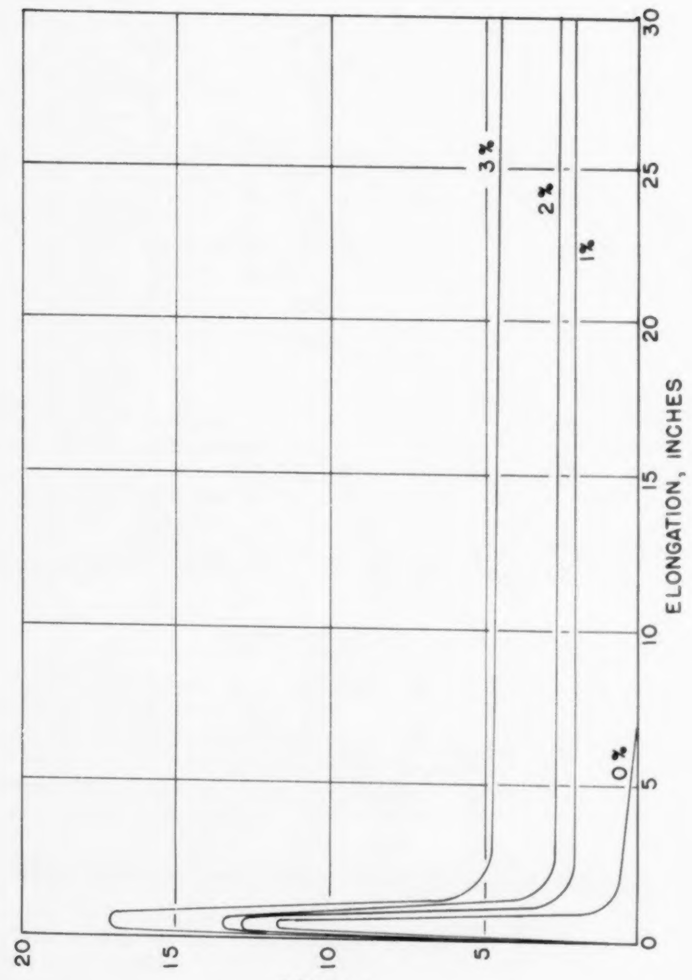


Figure 3. Typical curves formed during toughness and tenacity tests on blends containing natural rubber

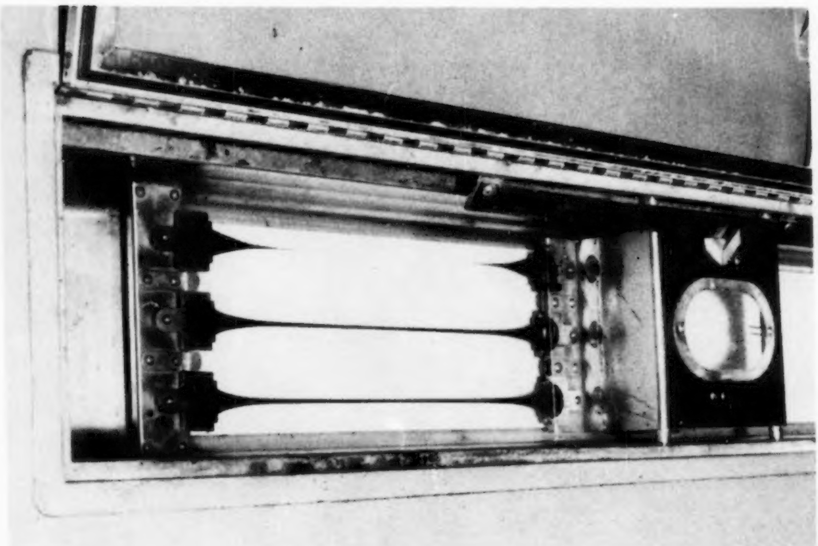
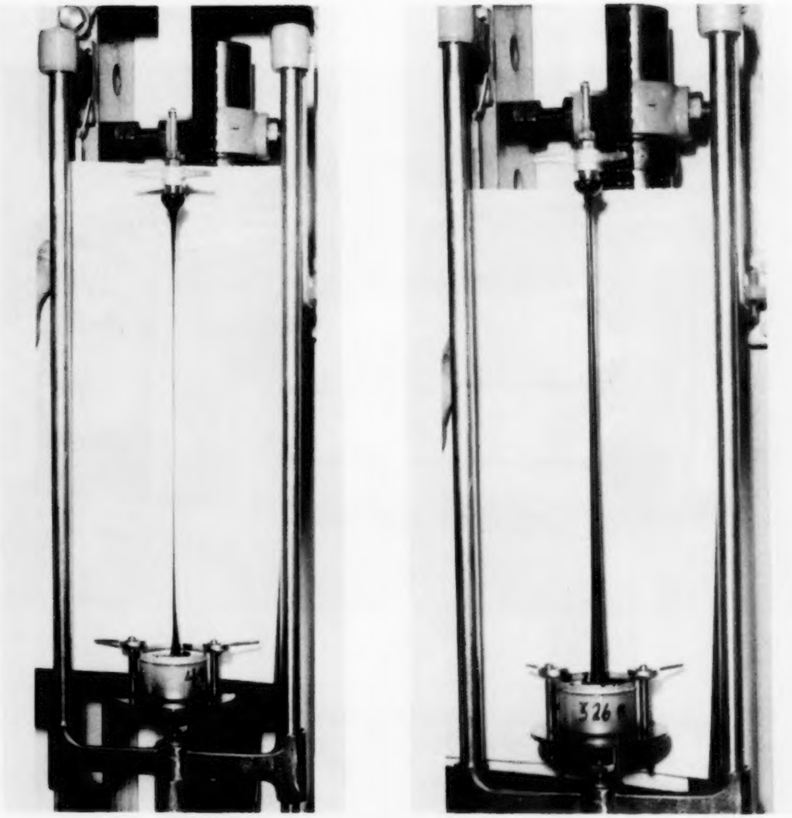


Figure 4. Typical elongation of materials during 39.2°F. ductility test

top - asphalt
middle - rubberized asphalt, 1% rubber
bottom - rubberized asphalt, 2% rubber



Asphalt Rubberized Asphalt

Figure 5. Typical elongation of test samples during toughness and tenacity test

Table 2. Results of tests on asphalts rubberized with 2 per cent natural rubber powders and various amounts of sulfur additive. Results of tests on latex blends are given for comparison.

Type of rubber	Sulfur 1/	Softening point	Penetration 77° F.	Ductility 5 cm/min. 77° F	Ductility 5 cm/min. 39.2° F	Toughness	Tenacity	Elongation
	%	° F		cm	cm	in. lbs.	in. lbs.	in.
Mealorub	0	119	101	150+	27	23	9	20
"	5	117	105	150+	26	18	8	14
"	10	117	109	150+	38	15	7	16
"	15	117	110	150+	47	23	11	15
"	20	118	106	150+	21	25	11	17
Pulvatex	0	125	90	150+	13	34	15	12
"	5	122	97	150+	24	30	13	20
"	10	120	100	150+	64	42	28	30+
"	15	120	102	150+	86	66	52	28
"	20	116	106	150+	37	34	19	19
Latex A	0	127	92	150+	13	43	25	15
"	5	121	106	150+	50	36	25	30+
"	10	118	104	150+	145	68	57	30+
"	15	120	105	150+	94	111	100	30+
"	20	119	107	150+	95	130	118	28

1/ based on per cent of rubber

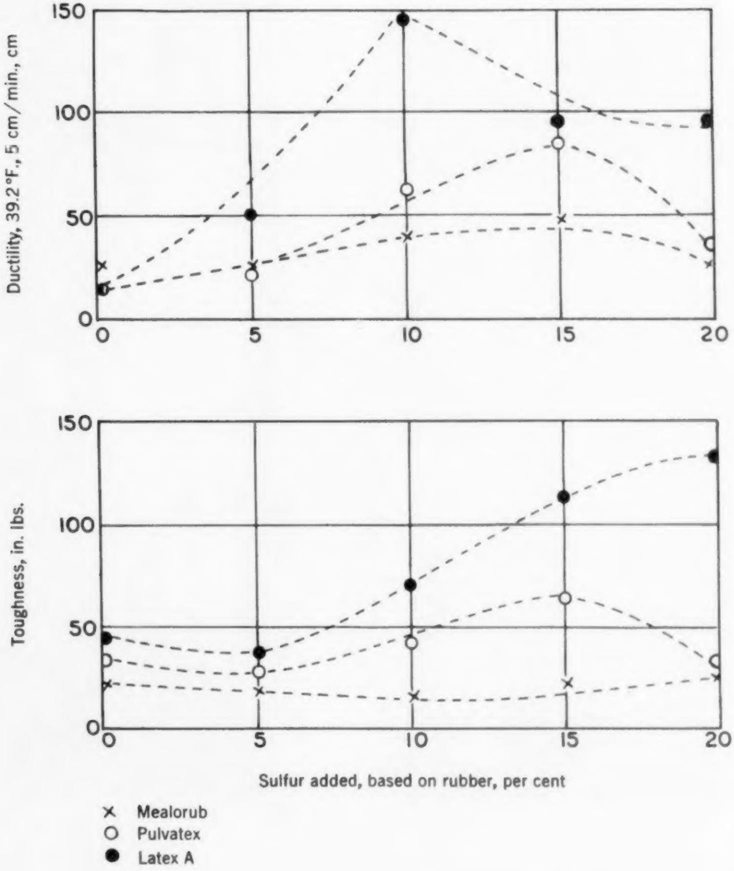


Figure 6. Effect of sulfur on ductility and toughness of blends containing 2 per cent rubber, prepared with rubber powders and latex

the same procedure used for the blends prepared with natural rubber latex. The results of tests on these rubberized materials, together with the properties of asphalts rubberized with the same amount of natural rubber latex, with and without sulfur, are given in Table 3.

A comparison of the ductility results shows that blends containing natural latex without sulfur, Neoprene, and SBR 2000 latices had low ductility values at 39.2° F., while those containing natural latex with sulfur, SBR 2006, and R-504 had high ductility at 39.2° F.

Based on toughness, the 2 per cent natural rubber blends with sulfur had the highest toughness and tenacity, R-504 was next, and the other materials were lower and had approximately the same values.

Other Asphalts Studied

Other investigations on the effect of rubber on the properties of asphalts have shown that the effect of any given rubber may vary when asphalts from different crude sources and methods of refining are used. Different asphalts may require different amounts of rubber to give the same degree of change in any given physical property. Also, the time and temperature of blending may vary with different asphalts to produce the same effects.

The data presented thus far in the report have been on samples prepared with one asphalt. Blends also were prepared with natural rubber latex and asphalts from several sources. No attempt was made to determine whether the amount of sulfur needed to give the optimum change in properties would vary with the asphalts from different sources. The blends were made with 1 and 2 per cent total solids from latex B and the sulfur was added on the basis of 15 and 10 per cent of the rubber respectively. Results of tests on these materials are given in Table 4.

The results shown for each asphalt without rubber and sulfur are for the asphalt after the same heating and stirring used to prepare rubber blends. Asphalt designated AC-1 is the same asphalt used in the first part of this report.

For all of the asphalts included here, the effects of incorporating natural rubber were similar although the changes were not of the same magnitude. In general, softening point, low-temperature ductility, and toughness and tenacity were increased. It is indicated that the amount of change in these properties is dependent upon the concentration of rubber. A more detailed study also may show that asphalts from different sources may require different amounts of sulfur to result in the optimum change in properties.

Process Tried for Preparing Larger Volumes of Rubberized Asphalt

In order to determine the practical aspects of rubberizing asphalts with natural rubber latex containing sulfur, several large-volume blends were prepared and used in surface treatment applications during 1957.

A 3000-gallon batch of asphalt was rubberized by heating the asphalt to 340° F. and adding the latex, containing 20 per cent sulfur based on the rubber solids. Approximately thirty minutes were required to add the latex and blending was completed in less than two hours. No trouble with foaming was experienced. The properties of the asphalt used and the rubberized asphalt, containing 1 per cent rubber solids, were as follows:

Table 3. Properties of rubberized asphalts containing various types of rubber

All materials shown contain 2 per cent rubber (total solids); percentage of sulfur shown based on rubber content

Type of latex	Sul-fur	Soften-ing	Pene-tration 77° F.	Ductility 5 cm per min. 39.2°F.	Stor-age Sta-bility	Tough-ness	Tena-city	Elon-gation
	%	°F		cm		in. lbs.	in. lbs.	in.
Natural B	0	126	98	13	3	33	17	13
Natural B	10	119	105	141	1	82	68	30+
Neoprene	0	113	120	43	1	29	19	10
SBR 2000	0	115	104	24	2	30	17	11
SBR 2006	0	117	107	150+	1	28	15	30+
R-504	0	121	105	150+	2	47	33	28

Table 4. Results of tests on blends prepared with natural latex B and sulfur using asphalts from different sources

Asphalt Desig. Source of crude	Rubber 1/ %	Sulfur 2/ %	Softening point °F.	Penetration 77°F.	Ductility 5 cm per min. 39.2°F. cm	Toughness in. lbs.	Tenacity in. lbs.	Elongation in.
AC-1	0	0	112	110	19	10	1	5
Venezuela	1	15	113	114	150+	34	24	30+
	2	10	119	105	141	82	68	30+
AC-2	0	0	110	119	11	9	2	4
Venezuela	1	15	114	116	28	17	9	19
	2	10	119	107	93	48	38	30+
AC-3	0	0	115	108	14	9	1.5	4
Midcontinent	1	15	111	122	39	31	21	30+
	2	10	113	118	110	65	57	30+
AC-4	0	0	113	108	13	11	2.5	7
Wyoming	1	15	116	106	117	50	40	30+
	2	10	121	99	60	106	93	30+

1/ total solids from latex

2/ based on per cent of rubber

	Asphalt	Rubberized Asphalt
Flash point, ° F.	590	575
Softening point, ° F.	110	114
Penetration at 77° F.	111	100
Ductility at 77° F., 5 cm/min., cm	131	150+
Ductility at 39.2° F., 5 cm/min.	20	55
Toughness, in.-lbs.	13	50
Tenacity, in.-lbs.	1.3	39
Elongation, in.	5	30+
Storage Stability	1	1

The above results show that the process for rubberizing asphalts given in this report is practical for preparing large volumes of material.

Summary of Study

This study was initiated to develop a method for rubberizing asphalts with natural rubber in latex form and to determine whether certain arbitrary characteristics of the material could be improved. Data has been presented to show that by adding small amounts of sulfur to the latex the blending conditions are improved and the effectiveness of the rubber on the asphalt is greatly increased. As compared with blends prepared with latex alone, the addition of small amounts of sulfur produced the following effects:

1. Reduced the time and temperature of blending.
2. Improved the storage stability.
3. Increased low-temperature ductile properties.
4. Increased toughness and tenacity.

In addition to the effects noted above, the data show the following:

1. The properties of an asphalt rubberized with natural rubber latex can be varied not only by the amount of rubber but also by using different amounts of sulfur.
2. Based on the asphalt, the amount of sulfur required to produce the above changes is very small. The maximum amount used in this study was 0.6 per cent.
3. The effectiveness of natural rubber in changing the properties of asphalt is greatly increased by the method presented in this study.
4. The properties of asphalts rubberized with natural rubber latex containing small amounts of sulfur compare quite favorably with the properties of asphalts rubberized with synthetic rubbers. In some cases smaller amounts of natural rubber would be needed to produce the same effects.

APPENDIX

I. Procedure for Storage Stability Test

Weigh 75 grams of the rubberized asphalt into a three-ounce tin ointment box of the type specified in the Method of Test for Penetration of Bituminous Materials, A.S.T.M. D 5.

Place the sample in an oven at 280° F. and heat for sixteen hours. At the end of the heating period remove the sample from the oven. Immediately slowly stir with a spatula and note the condition of the material, as follows:

(1) Stable—The rubberized material is homogeneous and smooth in texture and similar to the asphalt without rubber.
(2) Stable, granular—The rubberized material shows no distinct separation but has a grainy appearance compared to an asphalt without rubber.
(3) Unstable—The rubberized material has a skin or tough layer on the surface indicating separation of the rubber and asphalt.

II. Tentative Standard Method of Test for Toughness and Tenacity of Rubberized Asphalts

1. Scope

This method covers the test for determining the toughness and tenacity of asphaltic materials under prescribed conditions.

2. Apparatus

Sample container—A metal container in which the sample is tested shall be approximately 2-1/8 inches in diameter and 1-3/8 inches in depth. This is the same container specified in A.S.T.M. method D 5 for determining the penetration of bituminous materials.

Tension head—The tension head shall consist of a polished metal hemispherical head having a 3/8 inch radius, to which is integrally connected a 1/4 inch diameter stem, approximately 2 inches long, fitted with a flanged head to permit connection to the testing machine. The stem of the tension head shall be fitted with a small pin to prevent twisting of the head while adjusting. The stem of the tension head shall be threaded to permit accurate lowering of the hemispherical head into the asphalt in the container and fitted with two nuts to lock the head at the proper level.

Spider—The spider support for the tension head shall consist of a cylindrical center section through which the stem of the tension head may freely move parallel to the axis of the cylinder. The inner wall of the cylinder shall be grooved to receive the pin mounted on the stem of the tension head, which groove and pin operates to prevent twisting of the head during adjustment of the head level. The spider cylinder shall be fitted with three arms extending from the center and notched to receive the lip of the container, thus centering the spider and the tension head.

Testing machine—The testing machine for pulling the asphaltic material shall be capable of a uniform vertical movement of 20 inches per minute and a load capacity of not less than 50 pounds. This machine shall be equipped with a continuous graphic recording device to measure the forces and elongation involved. The machine may be similar or equal to a Model L-3 Scott Tester (Fig. 7) or an Instron Tensile Testing instrument.

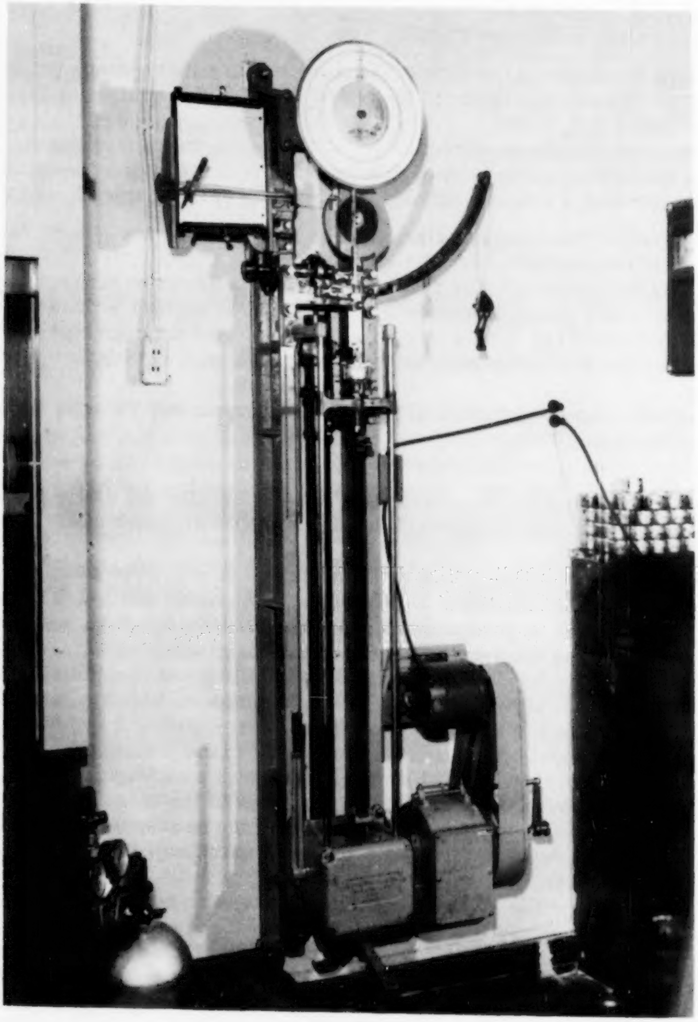


Figure 7. Model L-3 Scott Tester used for toughness and tenacity tests

3. Preparation of Sample

The sample shall be prepared by heating the material to approximately 180° F. above the softening point (but under no conditions to over 375° F.), carefully stirring to remove all air bubbles, lumps, or chunks. Approximately 50 grams of the heated asphalt shall then be poured into the test container. Immediately the tension head, having first been carefully cleaned with a suitable solvent and wiped dry, and mounted in the centering spider, shall be placed over the cup and the hemisphere carefully lowered by means of the locknuts until immersed in the hot asphalt to a depth of exactly 3/8 inch. Care must be taken that no air bubbles exist in the asphalt under the tension head, as such bubbles will create serious errors.

After placing the tension head, the cup and head shall be cooled in air for not less than 60 minutes nor more than 90 minutes, and then placed in a water bath held at 77° F. After not less than 60 minutes nor more than 90 minutes, the specimen shall be removed from the bath and immediately placed in the testing machine and tested. All charts, gears, and other parts of the testing machine shall have been prepared and placed in readiness before placing the specimen in the machine.

4. Procedure

The testing machine shall be run at a rate of pull of 20 inches per minute, and a continuous automatic recording made of the stress-strain values obtained. The pull shall be continued until the asphalt column breaks, the forces reach a measurable zero value, or the limit of pull of the machine is reached. Whenever possible, the test shall be run in a room in which the air temperature is maintained at 77° ± 5° F. In the absence of constant temperature, the tests on the rubberized and unrubberized specimens shall be run at the same room temperature.

5. Calculations

Toughness—The toughness of the asphalt sample is calculated in the inch-pounds of work required to separate the tension head and cup under the test conditions. Using the stress-strain curve obtained from the test, the total area under the curve may be computed in terms of inch-pounds by the method of squares or other equivalent means.

Tenacity—The tenacity of an asphalt is calculated as the work in inch-pounds required in that portion of the stress-strain curve obtained in the toughness test in which relatively small forces are exerted over appreciable distances. The tenacity is represented by that area under the total stress-strain curve obtained by extending a tangent on the portion of the force curve as it decreases from a maximum load value (peak load) to the zero force line. The area under the curve formed during elongation is the tenacity in inch-pounds.

6. Report

Two individual tests shall be made on each sample and both the results and their average shall be recorded.

Literature Cited

1. "New Concepts for Rubberized Asphalts," J. R. Benson, Consulting Bituminous Engineer, Denver, Colorado.

2. "Rubberized Asphalt—Wyoming Experiment," F. B. Odasz and R. V. Witter, Husky Oil Company, Code, Wyoming; Roads & Streets, November 1955, January 1957.

3. "Seal Coats with Latex Tested," W. H. Alcoke, Kentucky Research Foundation, University of Kentucky; Roads & Streets, July 1955.

Journal of the
HIGHWAY DIVISION
Proceedings of the American Society of Civil Engineers

CONTENTS

DISCUSSION
(Proc. Paper 1652)

Note: Paper 1652 is part of the copyrighted Journal of the Highways Division, Proceedings of the American Society of Civil Engineers, Vol. 84, HW 2, May, 1958.

THE USE OF TECHNICIANS IN HIGHWAY ENGINEERING[a]

Closure by Scott H. Lathrop and Francis J. Farias

SCOTT H. LATHROP,[1] A.M. ASCE and FRANCIS J. FARIAS.[2]—The original paper discussed the general subject of making the best possible use of technicians in the field of highway engineering. It described certain steps in the field of classification and organization which had been taken by one organization in working toward this end. Several times the point was made that the true engineering work would still have to be done by professional engineers.

In the particular field mentioned by Mr. Sawyer, only casual mention was made of the fact that in the area of bridge-construction inspection the possibility of using some inspectors with craft background rather than engineering background was being explored. In this field, as well as in the others discussed, it was intended only that technicians should supplement engineers and make their use more efficient, not that they should supplant or eliminate them altogether. The writers recognize, as does Mr. Sawyer, the necessity for having enough engineers on any construction project, bridge or highway, to handle any engineering problems which may arise.

It is possible that some misunderstanding could result from differences in inspection policy. In California inspection of such phases of construction work as concrete pouring, steel installation, etc., may well be more detailed than in other jurisdictions. If this be true, it could be that there would be more assignments at the technician level available than would be true in an organization which relied more upon inspection of the final product.

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a. Proc. Paper 1250, May, 1957, by Scott H. Lathrop and Francis J. Farias.
1. Senior Highway Engr., State Div. of Highways, Sacramento, Calif.
2. Associate Personnel Analyst, Calif. State Personnel Board, Sacramento, Calif.

OPERATION OF URBAN EXPRESSWAYS[a]

Discussions by Charles E. De Leuw and Karl Moskowitz

CHARLES E. DE LEUW,[1] M. ASCE.—Mr. Barnett's paper is an admirably frank discussion of the need for further critical analysis of the role of urban freeways. He knows, perhaps better than anyone else, the potentialities and the limitations of this type of transportation artery. His warning that freeways alone will not solve all of our urban transportation problems is especially timely in view of the speed with which such arteries are being planned and built under the impetus of the Federal Highway Act of 1956.

Present traffic volumes, Mr. Barnett points out, are repeatedly causing disturbing breakdowns of flow on freeways. These volumes will be far exceeded in the next few years as extensions of the freeways attract traffic from the large suburban areas. Volumes will increase even more rapidly than now contemplated, however, unless vast improvements in public transportation are made. In few cities, unfortunately, are there early prospects of new facilities for the transit patron comparable with the new roadways currently being provided the motorist through the expenditure of billions of dollars.

The extent to which the shift from transit to private vehicle might go is indicated by analyses of traffic data. Care and technical skill are required, however, to interpret properly the commonly available statistics. For example, raw tables of counts of persons, by mode of transportation, entering and leaving a central business district are often totally misleading. Any comparison between use of autos and transit based on such tables is rendered almost meaningless by the relatively high proportion of through traffic carried by automobiles as contrasted with the few people who use public transit for trips passing entirely through a central business district.

It is more accurate to determine the proportionate use of the two principal modes of transportation by interpretation of such cordon count statistics by means of accumulation charts. Such an analysis for Chicago's Loop reveals that at two o'clock in the afternoon approximately one person in eight who is in the area has arrived by automobile, while the other seven have arrived by public transportation. It is readily seen that in the large cities a small shift from public transit could double or triple the load currently estimated for proposed freeway systems.

It has been assumed in making transportation plans for several large cities that freeway operation of buses in the general traffic stream will fulfill the need to provide the same advantage for the transit patron as the motorist will receive. Speed and capacity on freeways sometimes fall to zero, however, for reasons which Mr. Barnett has described as "normal and to be expected

a. Proc. Paper 1374, September, 1957, by Joseph Barnett.
1. De Leuw, Cather & Co., Cons. Engrs., Chicago, Ill.

occurrences." At such times the motorist usually has some choice of route and sufficient flexibility in his movement so that he can detour around the blockade or seek other less congested routes on subsequent days. The transit passenger has no such choice. If he is caught in a blockade, which, according to Mr. Barnett, "it is not unusual to take hours to unravel," he has no choice but to get off the bus and walk to his destination. A few such experiences would undoubtedly discourage use of bus transportation. The erstwhile transit patron would thereafter use his own automobile. If trips to the central area proved to be too frustrating, he would seek alternative places to work and shop—but still by automobile.

The wide dispersal of our metropolitan areas instigated by the automobile makes the motor bus, rather than the fixed-rail vehicle, the logical type of equipment to serve the outer residential areas. At some point on the trip to the business district, however, the bus may encounter freeway congestion with which it cannot contend. One solution is to remove the bus from the general traffic stream at this point and route it over an exclusive right-of-way to a downtown terminal. Another method is to transfer the bus passengers to a short rail line, the high cost of which may be justified by the concentration of passengers from several bus lines. With either method, buses can adhere to schedules, and this is basic to the operation of any rapid transit system, whether rail or bus.

During the past four or five years, an awareness has developed on the part of the more astute municipal authorities that urban freeways will not solve all their transportation problems. Comprehensive transportation plans have been prepared or are under way in such cities as Boston, Chicago, Philadelphia, St. Louis, Washington, D. C., Montreal and Toronto. A report on commuter transportation in the New York metropolitan area is currently being compiled by the Metropolitan Rapid Transit Commission based on a number of consultants' reports.

Express bus operation on freeways has been authorized in almost all cities where permission has been sought by the operating company. In many instances, special facilities have been provided for bus stops along freeways as a part of highway construction. In Chicago, a two-track rail rapid transit facility is under construction on the Congress Street Superhighway. The cost of the right-of-way, earthwork, drainage, and cross-street structures over the widened center mall were borne as a part of the cost of the highway facility. The tract, station facilities and appurtenances are being provided through an issue of general obligation bonds which were overwhelmingly approved at a public referendum. Other similar installations in Chicago are in the planning stage.

In many cities besides Chicago there is a growing recognition on the part of the general public that transit is an essential function. Few thoughtful citizens will deny that they are benefited by good public transportation whether or not they use it regularly. The cost must be borne in part by the citizens of the community as a whole, they acknowledge, just as they support parks, sewers, fire and police departments, cultural institutions, and other amenities of urban living. The problem has been to find an equitable way, under the usual archaic forms of municipal organization, of distributing that portion of the total cost which should be a public obligation.

For some cities, such as Los Angeles and San Francisco, state laws have been passed which establish new administrative organizations to plan, finance, build and operate public transportation facilities within a metropolitan area

without regard to municipal boundaries. In many places, even more comprehensive legislation will be required since several large cities straddle state lines and affect literally scores of separate municipalities. The metropolitan type of government is in actual operation in Miami and Toronto and one is proposed for the Seattle area.

In all cities where metropolitan administration of public transportation is planned or in operation, there is urgent need for close collaboration with the agencies planning urban freeways. The economies and other advantages of combining both public and private transportation in one facility are so great that separate and competing systems would be a tragic waste of our resources.

The current highway program promises to bring great benefits, particularly to our more congested urban centers. As Mr. Barnett says with characteristic conservatism, however, "To keep the number of lanes within reason . . . mass transit may be called upon to reduce the private transportation volume." That call, to be answered effectively, must come while the freeways are in the planning stage.

KARL MOSKOWITZ,[1] A.M. ASCE.—It is true, as Mr. Barnett says, that traffic flow on urban freeways often breaks down at peak volumes. At such times, all traffic operates on a stop-and-go basis, with long lines of waiting vehicles behind each bottleneck or inlet where additional cars come into the stream. It is also true that if the volume could be kept low, traffic would flow at high speeds.

It is not true, however, that capacity reaches zero when the above condition occurs. The rate-of-flow under such conditions is extremely high.

Relation of Speed and Capacity

The figure in the Capacity Manual that Mr. Barnett has reproduced as his Fig. 2 has given rise to a fallacy which is widely held, even among traffic experts. The upper curve of this figure shows that speed is reduced as volume increases. In this curve, volume is the cause and speed the effect, i.e. speed is the dependent variable. The lower curve is a mathematical truism showing the maximum volume that can occur at a given "speed"; in other words, volume is plotted as a dependent variable.

But "speed" is not what shows on the speedometers of the cars involved; it is simply an undefined distance divided by the average time it takes the cars to go that far. The volume is the number of cars that cross a line in a given length of time; the line has no length in the direction of travel and the speed is therefore indeterminate. For example, if 1200 cars an hour come up to a stop sign, stop, and proceed, what is the "speed" at the stop line, or on the graph? If this "speed" is related to the 1200 vph, then what is the speed of 600 vph that each do exactly the same thing?

Vehicular motion must not be confused with rate-of-flow. Rate-of-flow is a slope with number as ordinate and time as abscissa. It is not a function of speed of vehicles. The vehicles can stop-and-go, as at a traffic signal, or stop sign, at a very high rate-of-flow. Similarly, the rate-of-flow on a freeway is very high with stop-and-go operation.

It should not be necessary to demonstrate theoretically that rate-of-flow is

1. Senior Highway Engr., California Div. of Highways, Sacramento, Calif.

independent of vehicle speed, because there are so many practical examples to observe. One such example[2] is the downtown intersection of the Hollywood and Harbor Freeways in Los Angeles. Fig. A is a photograph showing the west leg of this intersection, with westbound traffic coming toward the bottom of the picture. It is believed that the jamming in the vicinity of this interchange is typical of the problem Mr. Barnett is concerned with. Stop-and-go operation is prevalent on one or more approach legs for 2 or 3 hours daily. Yet at this location, the westbound traffic leaving the intersection on four lanes amounts to 8,000 vehicles per hour, including about 250 trucks and buses. Every last one of these vehicles has started from a standing start some place in the vicinity of the merging area. This rate-of-flow is hardly "zero". In fact, it is doubtful that four lanes on a rising grade line with 3% trucks would ever carry any more traffic regardless of how many prior ramps were closed down.

Delay and Capacity

Before an intelligent appraisal can be made of the equity of closing a freeway to some traffic while leaving it open to other traffic, the nature of delay and its causes must be understood. The typical delay occurring in American cities during the rush hour is not caused by vehicles going slow; it is caused by waiting for vehicles that got there first to go through bottlenecks at the rate of one every 2 seconds in each file. The delay causes slow speeds, not the other way around.

Plotting the cumulative number of cars passing a point as ordinate and time as abscissa, as in Fig. B, is a useful device in helping one to understand delay. If the rate of demand is known, it is also a useful device for computing the amount of delay. The latter application can be used in connection with a lane block such as illustrated in Mr. Barnett's Fig. 1. (It can also be used for determining delay at signalized intersections. Still another use for such a diagram is the determination of the time period that should be used for describing flow or capacity.)

In Fig. B, the upper line is the normal flow, or demand, at the location where the lane is blocked. The lower line is the capacity. The hatched area in between is the total delay in vehicle-hours or vehicle-minutes. By definition, the slope of the line is the rate-of-flow in vehicles per unit of time.

In plotting this graph, it was assumed that the vehicle in Fig. 1 stopped at 5:05 and started up again at 5:21. During this time, the two open lanes carried traffic at a rate of 3200 vph due to the turbulent transition from 3 lanes to 2 (with a smooth transition it would be around 3800 to 4000 vph). As soon as the lane block is removed (5:21) the three lanes start carrying traffic away from the jam at the rate of 5400 vph, which is about normal possible capacity. The front end of the reservoir of stopped cars will start to recede, and at 5:22 traffic will look normal at the point of former blockage; it will be moving about 45 mph at 5400 vph. It can be seen that although the lane is blocked for only 16 minutes (5:05 to 5:21), the stoppage, or "complete failure", as Mr. Barnett calls it, lasts until 5:47, or 42 minutes. Assuming no intermediate entrances to the freeway, and a density during stop-and-go conditions of 300 vehicles per mile (52.8-foot spacing in 3 lanes), the 500 vehicles suffering

2. Many other examples are given in "Freeway Capacity Study, 1956." (Ref. 1)

FIGURE A. West Leg of Interchange Between Harbor and Hollywood Freeways, Hollywood Freeway in Foreground.

delay at 5:21 will back up 1.67 miles before the front end starts to move at normal speed again.

This 1.67[3] miles of jammed freeway is what Mr. Barnett refers to as complete failure, and it is not intended here to dispute that term. However, traffic flow does not halt, and even though the jam lasts 42 minutes, the greatest individual delay is about 6 minutes.

Incidentally, it can be seen that observations purporting to relate vehicle speed and rate-of-flow at any point behind the point of blockage are meaningless until the front end of the jam has receded to the point of observation. This applies whether the blockage is temporary as in this example or permanent, where three lanes transition to two with concrete curbs. Many traffic observers fail to realize this.

Considerations of Equity

A designer of a beautiful transportation facility naturally hates to see it "break down". When he sees vehicles stopped on the travel lanes because the demand exceeds the capacity, he knows it has not failed, but some of the vocal non-engineering elements of the community holler "failure", and the engineer knows that by reducing the flow he can keep his customers moving. An obvious way of reducing flow is to shut down some of the entrances. Ergo, shut them down.

An immediate technical problem in a case like that shown in the photograph Fig. A, where two freeways cross each other, is to determine which of the feeding freeways to close down so that the other one will work.

A philosophic problem arises when the freeways are paid for by all the motorists instead of just those who would get the deluxe ride by shutting out the others. Since the Federal Highway Act of 1956 set up a "Highway Trust Fund" to be collected from all road-users, not just transcontinental travelers, this problem would have to be resolved for Interstate Highways as well as other freeways.

Scores of trial runs throughout the Los Angeles area, where freeway jams are a daily occurrence at several points, show that the freeway route is quicker than the surface street route in <u>every</u> case, even during the peak hours when jams cause delays of as much as 20 minutes in a ten-mile run. Contrary to the vocalization referred to in a preceding paragraph, the customers, by their choice of route, do not confirm that the freeways have failed—at least not in comparison with any other choice available. By trial and error, some of them have deserted the freeways for what they consider a better route, and others have returned. The total delay to all motorists tends to minimize through this method, just as water tends to level out in a tank full of baffles. Besides the almost insurmountable problem of mathematically minimizing delay as accurately as the motorists themselves do it, the American philosophy does not lend itself to dictating to different segments of the population which way they shall go.

Implicit in the proposals to shut down entrance ramps, is that the "through" or long-distance traveler is entitled to a fast ride even though the short

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3. 1.67 miles is the maximum length of the jam. At 5:21 the front end starts to recede at a faster rate than the rear-end piles up. The mathematics of how far the rear-end will back up before the jam is finally dissipated at 5:47 is left to the reader.

tripper may be penalized. Is it not just as feasible for the long-distance traveler to plan his trip so as not to hit a metropolitan area during the peak as it is for the commuter to duck out of the office a half-hour early?

If it were true that such control would increase the capacity, as stated in Mr. Barnett's final sentence, then the public would probably accept it. But it has not been shown that capacity is reduced when freeways jam; actual counts show just the reverse.

REFERENCES

1. Freeway Capacity Study, 1956. By G. M. Webb and Karl Moskowitz. Proceedings Highway Research Board, Vol. 36 (Jan. 1957).

2. Intersection Capacity. By G. J. Webb and Karl Moskowitz. Proceedings, Seventh California Street and Highway Conference (1955).

3. Los Angeles Metropolitan Peak-Hour Driving Study. Engineering Department, Automobile Club of Southern California, June, 1957.

4. Motion Picture "Freeway Traffic Flow". California Division of Highways, 1956. (First exhibited at 26th Annual Meeting, Institute of Traffic Engineers.)

5. Speed and Delay Runs on Freeways and Surface Streets. California Division of Highways, District VII, Unpublished files.

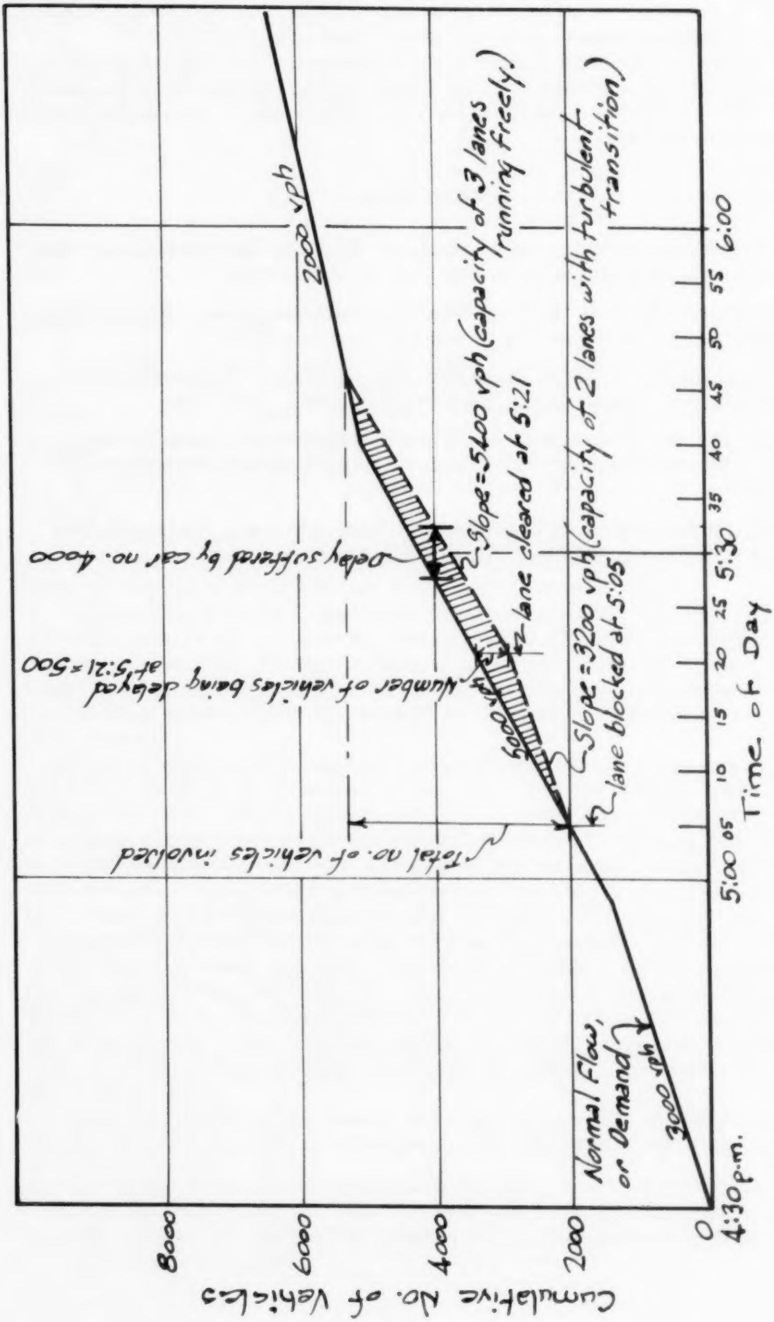

FIGURE B. Showing Relationship of Capacity to Delay

THE CONSULTING ENGINEER'S ROLE IN THE HIGHWAY PROGRAM[a]

Discussion by Paul L. Nichols

PAUL L. NICHOLS,[1] M. ASCE.—State highway departments have built up well-trained engineering departments to survey, design and supervise construction of the ordinary annual road program. The departments take young men fresh out of high school or college and train them in this specialty of civil engineering. The writer has been through such a training program and so has seen at first hand the excellent job State forces have done on the thousands of miles of rural roads and super highways connecting cities and towns.

However, Mr. Isaak makes some good points when he says that (1) The 41,000 mile Interstate System will require approximately 700,000 sheets of plans. It will also require a corresponding amount of special specifications. And from the contractor's standpoint, the plans and specifications need to be clear and easily understood. (2) The state highway departments alone cannot begin to cope with this engineering problem with their own forces but it will be their responsibility to organize the job. (3) By contracting engineering work to consultants, the state departments can extend their own capacities for production without the necessity for building up their own forces beyond the level required to take care of their continuing work load. (4) Consultants have the advantages of greater flexibility to increase or decrease their organizations; the ability to attract needed talent by a more favorable salary scale. By retaining consultants the public agency pays for desired services without increasing its own recurring payroll. (5) Beyond the basic need for additional manpower in the present program, there will also be numerous problems of a specialized technical nature.

State highway departments have not been able to afford to keep large staffs of experienced engineers and specialized engineers due to their limited pay scales and inadequate annual budgets. They can now obtain the services of large staffs of experienced engineers and specialized engineers from consulting firms.

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a. Proc. Paper 1380, September, 1957, by Elmer B. Isaak.

1. Cons. Engr., Kailua, Hawaii.

SIGNIFICANCE OF TESTS FOR HIGHWAY MATERIALS: BASIC TESTS[a]

Discussion by Jose A. J. Salas and V. Escario

JOSE A. J. SALAS,[1] and V. ESCARIO.[2]—This paper is very useful and fulfills a definite need. In fact, engineers who are involved for the first time with testing for road construction, need some sort of brief explanation of what is the significance of each test, which cannot be found in text-books in a condensed way.

These are the reasons why the writers read this paper with interest, as we think it is worth be distributed among the Spanish engineers. We wish, however, to make some observations about a few points with which we do not quite agree.

Mechanical Analysis

The use of this term should be discontinued, and it should be replaced by grain-size analysis, texture analysis, or any other. This term dates from the time when soil science was based on chemical analyses and was used to illustrate an analysis which was not chemical in nature. This term is inadequate at present, for it could be more properly applied to the shear or consolidation tests.

The writers wish to point out too that the hydrometer analysis has been more widely used than necessary, and that only on rare occasions are its results needed. It is a difficult test, and it is often performed in field laboratories lacking equipment and inexperienced personnel. This results in thousands of erroneous hydrometer analyses, that cannot cause serious results as, luckily, they are practically ignored. For common practice, the sieve analysis up to the No. 200 sieve, together with the Atterberg Limits will suffice.

The writers must remark that with the standards usually employed, it is impossible to obtain accurate results when dealing with saline soils, that are so abundant in arid climates. If the soils are not previously washed, and this requires several days or the possession of a costly centrifuge of great size, it is impossible to get a good dispersion.

The assertion that the hydrometer analysis is conducted on a sample of the material that passes No. 200 sieve is erroneous for a considerable number of the modern standards. It is useful for knowing the grain-size distribution of the portion passing No. 200 sieve, but it is used with a sample passing a coarser mesh.

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a. Proc. Paper 1385, September, 1957, by Taylor D. Lewis.
1. Ingeniero de Caminos, Canales y Puertos, Madrid, Spain.
2. Ingeniero de Caminos, Canales y Puertos, Madrid, Spain.

Finally, the grain-size limits quoted are by no means generally admitted, not even in the U. S. In particular, to classify as clay the fraction finer than 0.005 mm. is considered by a great number of engineers as erroneous, as between 0.005 and 0.002 mm. prevail the particles which are not mineralogically real clay.

Consistency Tests and Indexes

On page 5, in discussing typical test results, it is said that "for shrinkage limit, clays always range in values from 6 to 14, with silty materials most frequently showing values between 15 and 30".

Let us admit the Casagrande definition of clay, as that soil lying above the A-line of his well-known chart. According to Casagrande an approximate way for determining the shrinkage limit without running the test, consists in plotting in his chart the point representative of the soil and drawing a line parallel to the A-line; the point of intersection with the horizontal axis gives the shrinkage limit.

As it is said in the paper, the shrinkage limit is very seldom determined. For this reason the writers did not run enough number of tests in our laboratory to establish the range of these limits for clays and for silts. But if the graphical method of Casagrande is correct, the upper boundary of the shrinkage limit for clays would not be 14 but 20; for silts the lower limit would again be 20.

Nevertheless, the writers wish to state that in recent years, some laboratories which had abandoned the shrinkage limit have resumed its use, owing to its aptitude for the discovering of swelling clays. All values inferior to 10 correspond to a swelling clay. From 10 to 12, dubious. Over 12, it is quite sure that no dangerous swelling will occur. This data corresponds to the shrinkage limit of the ASTM standards, but the results obtained with other standards are very different, for the theoretical definition of the shrinkage limit is arbitrary and does not correspond with that resulting from the test.

In highway techniques, the ratio of natural moisture content to plastic limit is an indication of the soil drainage, or more precisely, the consistency index. When the soil is conveniently drained, under a pavement, its value falls near the plastic limit, though allowing for some variation according to the climate.

The sentence in the paragraph "Typical soil results": "normally, the silty soils will have the lower plastic limit" is not clear, but it can be given an erroneous meaning. Contrary to what it seems to say, of two soils having the same liquid limit, the more silty will have a higher plastic limit.

In "Methods of tests" the writers note the lack of the method for getting two points with <u>the same moisture content</u> and tracing the "blows-moisture content" line with a statistically predetermined inclination. A statistical analysis which is being conducted in our laboratory proves that this method is as accurate or even more as that of three points, interpolating afterwards a straight line with an arbitrarily chosen inclination.

Among the index properties we find missing the "sand-equivalent", which is highly useful for the identification of materials for sub-bases. It is very difficult to determine accurately the consistency limits of soils with PI < 6, but the employ of the sand-equivalent tests is especially indicated in this type of soils.

Moisture-Density Test

When referring to the Typical Test Results of the Moisture-Density Test (page 7) it is said ". . . This per cent varies from 90 to 95% for the more granular materials and 95 to 100% for the fine-grained silts and clays". This phrase gives the impression that the granular materials always require less compaction than the fine-grained ones. That is correct for the body of the fill; but that is not always true. In fact, it is often specified[3] that the granular sub-bases should be compacted from 95 to 100% of the maximum density.

It should be pointed out that its results have very often the significance of an index. In a great number of specifications, a Proctor maximum density of the soil not inferior to a certain value is required for some cases. The shape of the moisture-density curve is also indicative and some specifications forbid the use of soils having two maximii in this curve.

The optimum moisture is an index too, greatly approaching the plastic limit, and some authors consider it as having a closer affinity than this with the equilibrium moisture of the soil under a pavement.

Consolidation Test

With respect to the Consolidation Test, there is obtained another value, which is as important as C_c and c_v, that is to say the "preconsolidation load". To know if a clay is or is not preconsolidated, and to what extent, is in some cases the only purpose of the consolidation test, even more than the knowledge of the real value of possible settlements, which in highway practice do not always constitute decisive factors.

In the first place, the knowledge of the real extent of preconsolidation of the soil enables us to foresee the great or negligible magnitude of possible settlements. Secondly, this data is very useful for the computation of the stability.

Shear Test

In discussing the Tri-Axial Shear (page 10) it is said that the soil sample ". . . frequently consists of a 28-inch diameter cylinder . . ." which gives the impression that such is the most convenient size. The writers cannot tell what is the most "frequent" size used in the U. S., but we do not think that such size is really the most convenient. The bigger the sample the better the results, but then the sampling operations are very expensive. In fact, a tri-axial test needs three cylinders, and when dealing with undisturbed samples it is convenient to trim all of them out of the same slice in order to get them as uniform as possible. That is why, in order not to have to take too big samples, we in Spain use 1-1/2" diameter cylinders for fine grained soils. For remolded or stony soils we use 4" diameter cylinders. And, as far as we know, in Great Britain they use the same criteria, as well as in Sweden and Norway. In the U. S., at least in the Harvard University Soils Laboratory, the 1-1/2" diameter cylinders are most frequently used.

Later on in the same paragraph it is said "Generally the sample is saturated so as to represent the most critical condition . . ." The writers would say "sometimes the sample has to be saturated . . ." because we do not either think that the most frequent cases ask for saturating the samples.

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3. For instance, in the last Spanish and German specifications.

Referring to "Typical Test Results" for friction and cohesion (page 11) the range of "typical values" for clay soils is given as:

$$\phi = 0^\circ \text{ to } 15^\circ$$
$$c = 100 \text{ to } 1000 \text{ psi.}$$

The writers think these values are not correct. First of all, when speaking about friction or cohesion one should always mention whether he is talking about a drained or an undrained test. Here it seems as if the committee was speaking in general. In that case, ϕ may vary from 0° for an unconsolidated undrained test (Q) to perhaps 30° for a drained test (S). And taking, for example, the values given by Terzaghi and Peck[4]

$$\phi_S = 28^\circ \text{ to } 30^\circ \text{ (exceptionally as low as } 20^\circ)$$
$$\phi_{cq} = 14^\circ \text{ to } 20^\circ \text{ (exceptionally as low as } 12^\circ)$$

No one of those ranges of values coincides with 0° to 15°. This range might be true for shear-strength determinations made on partly saturated cohesive soils by means of Q tests.

As far as the values of cohesion given we find them extremely large. The writers do not mean that they are impossible, but they are by no means representative.

When discussing "Influence of the Methods of Tests" (page 11) it is said "For triaxial shear tests, the hydrostatic or water pressure in the void space between grains is a critical factor during loading. This 'pore pressure' is measured and evaluated".

As it is well known, the pore pressure measurement is very useful and common today, but quite often it is not carried out, for instance in a Q or a Q_c test when one is only interested in a total stress analysis.

4. "Soil Mechanics in Engineering Practice". Article 15, page 87.

ADAPTABILITY OF INTERCHANGE TYPES ON INTERSTATE SYSTEM[a]

Discussion by G. D. Love

G. D. LOVE,[1] J. M. ASCE.—Mr. Leisch's paper covering the adaptability of the different types of interchange designs at intersections of Interstate highways and the different types of intersecting highways has presented a wealth of basic interchange design information that should prove to be very useful to engineers in the highway field.

At interchanges with minor crossroads, Mr. Leisch points out the advantage of the diamond form of interchange. However, he considers that the diamond is an inappropriate interchange at minor (rural) crossroads because it is so conducive to wrong way movements. Without a doubt, the terminal design of the diamond ramp - minor road intersection is more conducive to wrong-way maneuvers than the so-called parclo-B interchange design. On minor rural roads, the traffic stream is made up of predominantly local traffic. As such, the motorists are very familiar with the immediate local road - interstate highway intersections and the directional flow of traffic on the Interstate highway. It seems improbable that motorists who use a facility at frequent intervals are prone to make wrong-way movements, notwithstanding the fact that the design of ramp-crossroad intersections of diamonds may invite possible wrong way maneuvers. Therefore, where traffic is primarily local in nature, as is the case on minor rural roads the advantages Mr. Leisch presents against the use of a diamond design seem to be minimized and are more than offset by the advantages associated with this type of design, some of which are listed as follows:

(1) As a general rule, diamond interchanges require less right-of-way and are less expensive to construct than loop designs.
(2) They provide a more direct connection and shorter travel distances.
(3) Diamond interchanges can be adapted to existing terrain features with minimum effort.

Although standard interchange designs are desirable as guides they should not be utilized as the sole basis for design. All interchanges should be considered as individual problems with due consideration given to all types of interchange designs and to all factors that must be evaluated before a good design can be developed. When standard designs are used, there is a tendency to apply them indiscriminately, resulting in stereotype plans that do not reflect professional engineering quality.

a. Proc. Paper 1525, January, 1958, by Jack E. Leisch.
1. Highway Design Engr., Albany, N. Y.

CONTINUOUS ORIGIN AND DESTINATION SURVEYS[a]

Discussion by J C Carpenter

J C CARPENTER,[1] M. ASCE.—This presentation by Mr. Hitchcock will be welcomed by traffic engineers as a description of a proposed orderly technique of high value. It will be of particular interest to those engaged in location and design. One origin and destination survey for a specific project serves temporarily to answer pertinent questions for that project. Designs must be made for the improvement to cover future use and when the trends are developed it is important that they be based on past indicators. If there have been no previous origin and destination surveys the future projection must be related to other trends such as population growths and similar statistics. Continuous origin and destination surveys as proposed by Mr. Hitchcock will provide reliably accurate data for future projections.

This discussion covers one of the important elements of origin and destination surveys. For continuous surveys and for "one time" surveys, it is essential that the locations of the origins and destinations be clearly established so that they may be used with confidence on future surveys. The customary procedure on present surveys is to subdivide the areas of origin and destination into arbitrary zones shaped to fit the requirements of the particular project under study. The use of coordinate locations for zoning is not intended to supplant the arbitrary zoning procedure. It will allow the development of a method of location of origins and destinations so that they may be assigned to properly designed arbitrary zones by machine methods. The coordinates of small colonies of origins and destinations will be recorded and these may be included in larger zones, as required.

Continuous origin and destination traffic surveys will provide excellent "back-sight" information for projection of traffic pattern trends into the future. Trends in traffic volumes, population, motor vehicle registration, gasoline consumption and other recorded statistics are now used as indicators for projection of traffic movement patterns. There are very few repeat origin and destination surveys which may be used as trend indicators for projection of elements of this type of survey into the future. In addition to the projection feature, many other valuable developments will result from continuous origin and destination surveys. Intensive promotion in the field of traffic engineering will be required to bring about universal adoption of the proposed procedure.

In a single origin and destination survey there are numerous important elements that must be carefully planned to insure reliable and comprehensive results. For cordon surveys requiring roadside interview stations the

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a. Proc. Paper 1625, May, 1958, by S. T. Hitchcock.

1. Senior Highway Traffic Engr., Coverdale & Colpitts, Cons. Engrs., New York, N. Y.

locations must be so selected as to measure the flow of traffic of maximum interest. Periods of interview (week days, Saturdays and Sundays and hours of interview each day), seasonal repeat studies to provide reasonable information to expand to annual traffic, minimum percentage of hourly traffic to be interviewed, and other equally important features must be carefully studied and programmed. When a schedule of continuous surveys is inaugurated, these, and other important elements will require long range planning to insure results that will be reasonably comparable.

Geographical zoning of the area of origin and destination locations is one of the most important parts of any origin and destination study. The locations of these origins and destinations for trips passing an interview station are established by interviewing the driver of the vehicle making the trip. In city surveys these locations are usually identified by the street address. In processing for analysis the locations are collected into zones which may be limited to the smallest area of interest in the study, such as a city block, a census tract, or a square delineated by a coordinate system. Examples of zoning layouts are described in Highway Research Board Publications for Detroit,[(1)] Dallas[(2)] and Sacramento.[(3)]

In rural surveys, origins and destinations need not be so closely pin-pointed as in urban studies. For these surveys outside of cities zone boundaries are established in a manner somewhat similar to the mapping of drainage area boundaries for determination of the size of opening for a bridge over the stream which drains the area. Arterial highways draining traffic from an area represent the stream in an origin and destination Highway survey. But traffic does not "seek its level" as does water in a stream. Hence zones established for one traffic survey are not likely to satisfy requirements of another survey in the same or adjacent areas.

After the zones are all laid out for a survey each one is assigned a number. These numbers are recorded on punch cards or other recognized recording media for use in processing with electronic or other types of computers. The zone thus becomes fixed in shape and it is impractical to modify the boundaries or subdivide it without expensive recoding of the field interview sheets.

The Bureau of Public Roads Turnpike Traffic analyses made in cooperation with State Highway Departments of Maine[(4)] and Pennsylvania[(5)] are examples of continuous origin and destination surveys. On the Maine Turnpike survey a system of zones was laid out to cover the whole United States. It was found that this zoning system used in Maine could not be adapted to the analysis of the Pennsylvania Turnpike traffic survey. Consideration was given to the development of a coordinate system for location of O & D but this would have required the recoding of all of the interviews on the Maine Turnpike analysis and could not be done at reasonable expense so the idea was abandoned and a new set of zones laid out as illustrated in the Public Roads article.

Origin and destination traffic surveys were made in 1953 for the Kansas Turnpike by the State Highway Planning Division for the Authority under the supervision of Coverdale & Colpitts, Traffic Engineers for the Authority. The zoning system laid out for this 264 mile expressway was planned to measure the flow of traffic to the eleven interchanges of the original plan. Before the analysis was complete an interchange was added at Bonner Springs and during construction another was added at East Lawrence and one at Kansas 15 in Wichita. Fixed zone boundaries on summary sheets could not be modified to subdivide the zones and the analysis of traffic that will use these three additional interchanges was difficult.

In 1954 an extension of the Turnpike from Wichita to Hayes was surveyed. The interview station on U.S. 81 south of Newton used on the original survey covered traffic which might use the new project. Zone to zone records obtained on the first survey were recoded but the resulting information was not entirely satisfactory.

When an extension of the Turnpike on Eighteenth Street in Kansas City was surveyed available data from several previous surveys in this area were studied. Very little of this information was usable and the State Highway Planning Department decided to develop a coordinate system to cover the whole United States for use in locating the origins and destinations on this project and on subsequent other surveys in the State. By this method applicable zone boundaries may be defined by limits whose location are expressed in X and Y coordinates. The origins and destinations in the zone can be assigned by machine processing the locations which are defined by coordinates of the same system. The coordinates of each origin and destination location are coded on the interview sheets and punched on a card for that particular trip and remain as a pin-pointed location record which may be used in all other surveys. The zone boundaries for other surveys may be located to best serve the project under consideration and origins and destinations can be assigned to the new zones by machine processing. The system is applicable to all origin and destination surveys in the State and may be used by all the States of the Union. It is described in a pamphlet entitled "Geographic Coordinate Method for Coding Origin and Destination Surveys" by the State Highway Commission of Kansas, Highway Planning Department. A brief description follows.

Each locality has been assigned a ten-digit code number based on its geographical location in relation to the south west corner of the State of Kansas which is at the intersection of Longitude 102 degrees and Latitude 37 degrees. Coordinates of this reference point at the southwest corner of the State were established as X equals 2,000.0 miles and Y equals 2,000.0 miles. All of the United States is in the first or north-east quadrant and hence there are no minus coordinates. See Fig. 1.

The X and Y coordinates for the system are computed by converting the respective latitudes and longitudes from circular degrees to miles. For this system the X ordinates were determined on latitude 38 degrees and 30 minutes which bisects the State. This procedure is not strictly accurate. The pamphlet was reviewed by Mr. C. A. Whitten of the U. S. Coast and Geodetic Survey who said, ". . . if the system is used primarily for coding and approximate distances say, correct within 5 per cent, there should not be any serious handicap in the use of the system. Naturally we would have recommended a coordinate system based on the Lambert Projection for the entire country, such as was used in Special Publication 238." S.P. 238 is entitled "Air-line Distances Between Cities in the United States by C. A. Whitten."

The geographic center of the United States is in central Kansas near the intersection of U. S. 36 and U. S. 281. For continuous origin and destination surveys throughout the United States a system of coordinate coding as now used in Kansas, refined by computation of the coordinates on the formulas used in S.P. 238 to provide correct mileages on the Lambert projection will provide a standard procedure which will allow comparisons to be made of origin and destination data based on the same locations for each annual survey. For continuous or individual surveys the coordinate system will provide a standardized practice which will result in a valuable store of coordinated information that cannot be accumulated under present practice.

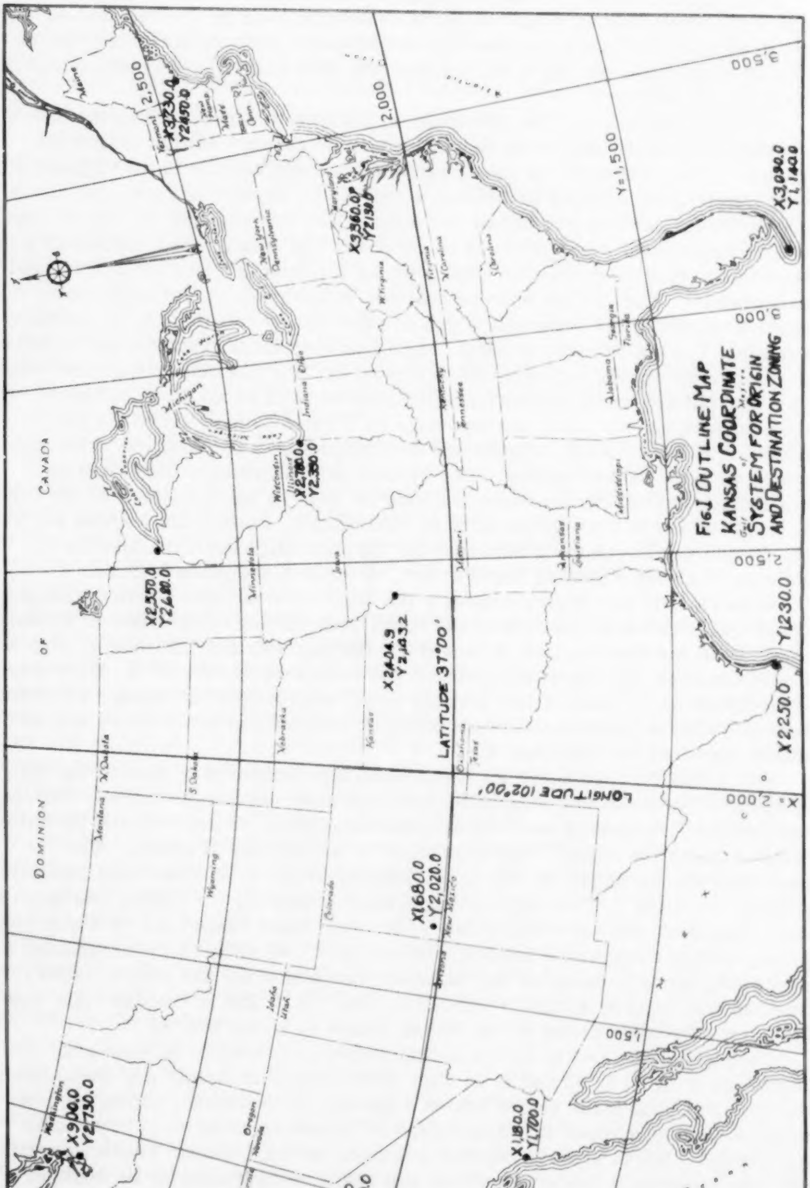


FIG J OUTLINE MAP KANSAS COORDINATE SYSTEM FOR ORIGIN AND DESTINATION ZONING

The following table compares the Kansas coordinates with those in S.P. 238. Airline distances are from 25th and Main Street, Kansas City, Missouri.

Location	KANSAS COORDINATES		AIR-LINE DISTANCES		Kansas Percentage of S.P.238
	X	Y	Kansas $\sqrt{dX^2+dY^2}$	S.P.238	
Kansas City, Mo.	2,404.3	2,143.2			,,, .
Portland, Maine	3,730.0	2,450.0	1,488	1,438	102.5
Washington, D.C.	3,360.0	2,130,0	960	943	101.8
Key West, Florida	3,090.0	1,140.0	1,212	1,249	97.0
Brownsville, Texas	2,230.0	1,230.0	925	924	100.1
San Diego, California	1,180.0	1,700.0	1,315.0	1,336	98.5
San Francisco, California	900.0	2,050.0	1,511	1,506	100.3
Seattle, Washington	900.0	2,730.0	1,635	1,506	108.5
Duluth, Minnesota	2,530.0	2,680.0	550	546	100.7
Durango, Colorado	1,680.0	2,020.0	733	733	100.0
Chicago, Illinois	2,780.0	2,330.0	421	414	101.5

In the Kansas system no allowance has been made for the convergence of the meridians and a degree of longitude has been assigned the same value at high and low latitudes so that east-west distances at high latitudes will be too great and at low latitudes too small. Skew distances have appreciable errors. The above table illustrates this point, but there are no errors in excess of 5 per cent except for Seattle. Before an attempt is made to apply this system to other States the coordinates should be adjusted to the Lambert projection as suggested by Mr. Whitten.

The use of coordinates for origin and destination location is not a new idea, although probably there has never been an attempt to apply it to the whole United States. California has used a state-wide grid since 1947.(3) It is based on the 5,000-yard Army Grid Zone "G" which covers all but the southeastern-most portion of California and is carried on most United States Geological Survey quadrangles. This coordinate system can be tied into the proposed Kansas system for the United States after the Kansas system has been refined to base it on the Lambert projection. Many California points such as those listed in Special Publication 238 may be converted to the Kansas system and related to the California grid. This will provide a system for use outside of California and an alternate for use in the State if desired.

Coordinates have been used in many city surveys. Mr. MacLachlan of California has said, "The idea of the system first occurred to us in late 1947 or early 1948 at which time an arbitrary grid was set up for the San Francisco Bay Area. The customary desire lines had been found to be somewhat bewildering and difficult to work with, and the irregular shaped zones then in common use occasioned great expense when any re-zoning had to be done.

"In the course of experimental work in the Bay Area, which was generally satisfactory, a State-wide grid became apparent.

"The system adopted has worked well for our Origin and Destination

studies and has not been further refined. Theory has not been pushed any further than foreseeable needs impelled." The advantages of the coordinate method are clearly set forth, in detail, in Mr. MacLachlan's article in the Proceedings of the Highway Research Board for 1949.(3)

The Kansas coordinate system was used in the origin and destination survey for the 18th Street Expressway in Kansas City, on the County-wide survey for Wyandotte County, on traffic studies in Kansas City, Missouri, on external surveys in Kansas at Augusta, El Dorado, Manhattan, Phillipsburg and Concordia and on the internal portion of the Wichita Metropolitan Area Survey.

City origin and destination surveys in Kansas are normally coded to the nearest tenth of a mile. The rural grid may be carried into the city but the usual practice is to shift the mile grid lines a slight amount so that they correspond to the section line arterial streets if they do not naturally do so. It is the majority opinion of the members of the Planning Department that the coordinate method of coding is as efficient and at the same time far more flexible than the arbitrary zone type of coding. The advantages of the system are set forth in the pamphlet published by the Kansas State Highway Planning Department. Fig. 2, a map of Wyandotte County, shows the coordinate grid on a five mile spacing. In the Greater Kansas City Area the street numbers were coded to the nearest tenth mile. Coding manuals prepared on State IBM machines were used thus avoiding searching for locations on maps. Similar manuals were prepared listing the coordinates of each locality in Kansas as well as for principal cities in other States of the Union. These code listings are thus firmly fixed and become standard coordinates for all surveys.

A coordinate system is being used for coding the locations of origins and destinations in the Chicago Area Transportation Survey now under way.

Distances between origins and destinations computed by coordinates are air- or straight-line lengths. These are important in comparing travel routes from distant locations, but of more importance is the resultant accuracy of direction of traffic flow. For most surveys the length of travel via present routes will be measured in the field or scaled from maps. A relation between air-line distance and over-the-road distance can be computed and applied to each movement.(1)

A coordinate method will be readily accepted in areas subdivided under the Public Lands system into townships and sections. In eastern parts of the country which do not have rectangular subdivision, application of the idea will be somewhat more difficult. For all States the Coast and Geodetic Survey has established Standard Plane Coordinate systems and through their triangulation systems many points have been accurately located in each State. When numerous points such as those listed in Special Publication 238 have been tied in to the refined Kansas coordinate system for any State, other points may be located on the Plane Coordinate Grid for that State by converting the distances in feet to miles or by obtaining the latitude and longitude of each point and converting it to the Kansas coordinate system using the formula and tables in Special Publication 238. The grid north for these Standard Plane Coordinates is not on the true meridian except at the central meridian but this is not important in the use of these coordinates for origin and destination surveys. An orientation is provided in those States where the section line does not exist and the city streets may run in every direction.

The development of a procedure of continuous origin and destination surveys as proposed by Mr. Hitchcock will provide much valuable information not now available for traffic studies. It will allow traffic engineers to make

much more accurate estimates of future travel and hence add permanent value to designs for projects. Not the least of the benefits will be the ability to relate traffic trends to other statistical data and to use the factors in areas where continuous surveys are not practical or economical. Continuous origin and destination surveys will add masses of data for listing sampling techniques such as are now available for sampling schedules for determination of traffic volumes. Use of the coordinate method of location of origins and destinations will provide accurate and identical information for use in comparison of the data over the years of operation. Development of coordinate control of origin and destination locations is one of the technical tools that should be inaugurated for one-time surveys even though the continuous surveys are not immediately instituted and it is a positive requirement for continuous surveys to provide correct comparisons.

The Kansas system of coordinates was developed by Mr. R. T. Fry, Supervisor, Urban Traffic Surveys, Highway Planning Department. Mr. Robert M. Willis, M. ASCE is Planning Engineer in charge of the Department. Both Mr. Willis and Mr. Fry have cooperated in providing information for this discussion and in placing the system in operation in Kansas. Credit is also given to Mr. K. A. MacLachlan, Manager Highway Planning Survey, California Division of Highways for valuable assistance in providing information about the California Grid for coding origin and destination surveys.

REFERENCES

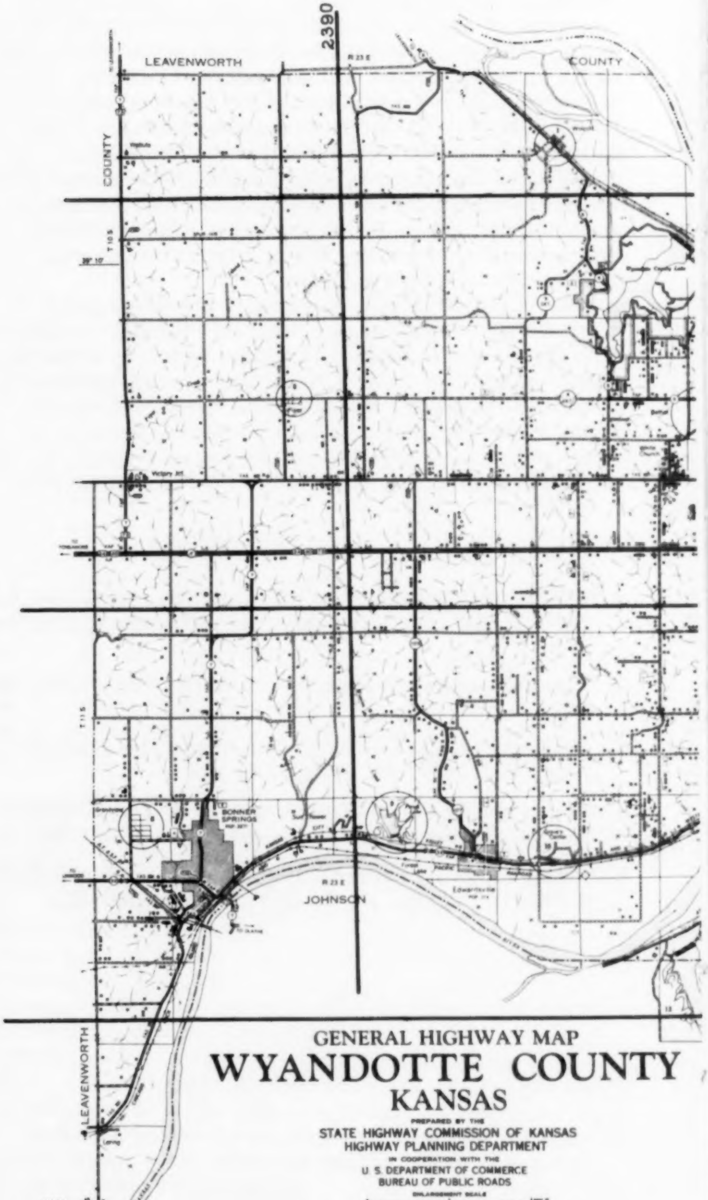
1. Detroit Metropolitan Area Survey, Parts I and II and Highway Research Bulletin 153, Directional Analysis of Vehicle Travel Desire, by Arthur T. Row.

2. Directional Contour Maps of Travel Desire by L. M. Braff, HRB Bulletin 153.

3. Coordinate Method of Origin and Destination Analysis, by K. A. Maclachlan, Proc. HRB 1949, Vol. 29, pp. 349-367.

4. Proportionate Use of Maine Turnpike by Traffic through Portland-Portsmouth Corridor, by J C Carpenter, Proc. HRB 1953, Vol. 32, pp. 452-463.

5. Pennsylvania Turnpike Traffic Analysis, by Daniel O'Flaherty, Public Roads, Vol. 28, No. 10, October, 1955, pp. 203-223.


2390
LEAVENWORTH
COUNTY
BONNER SPRINGS
JOHNSON
GENERAL HIGHWAY MAP
WYANDOTTE COUNTY
KANSAS
PREPARED BY THE
STATE HIGHWAY COMMISSION OF KANSAS
HIGHWAY PLANNING DEPARTMENT
IN COOPERATION WITH THE
U. S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
SCALE
1950
POLYCONIC PROJECTION

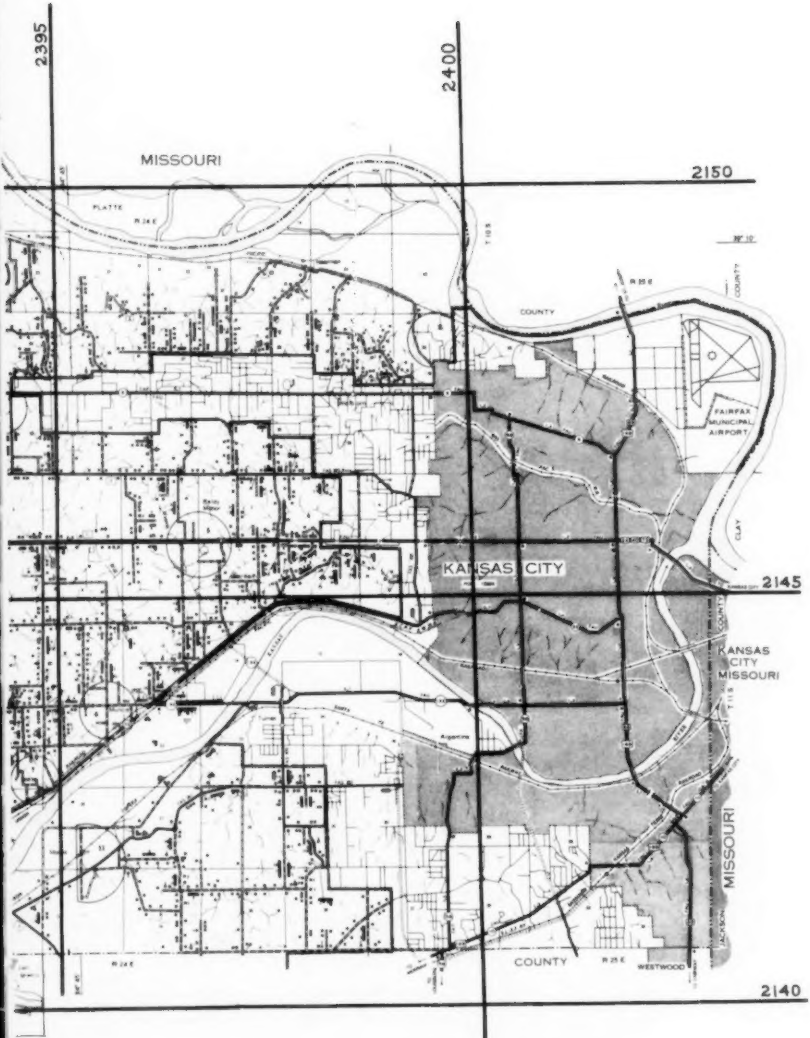


FIG.2 FIVE MILE GRID
KANSAS COORDINATE SYSTEM FOR
CODING ORIGIN AND DESTINATION SURVEYS

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1449 is identified as 1449 (HY 6) which indicates that the paper is contained in the sixth issue of the Journal of the Hydraulics Division during 1957.

VOLUME 83 (1957)

MAY: 1231(ST3), 1232(ST3), 1233(ST3), 1234(ST3), 1235(IR1), 1236(IR1), 1237(WW2), 1238(WW2), 1239(WW2), 1240(WW2), 1241(WW2), 1242(WW2), 1243(WW2), 1244(HW2), 1245(HW2), 1246(HW2), 1247(HW2), 1248(WW2), 1249(HW2), 1250(HW2), 1251(WW2), 1252(WW2), 1253(IR1), 1254(ST3), 1255(ST3), 1256(HW2), 1257(IR1)[c], 1258(HW2)[c], 1259(ST3)[c].

JUNE: 1260(HY3), 1261(HY3), 1262(HY3), 1263(HY3), 1264(HY3), 1265(HY3), 1266(HY3), 1267(PO3), 1268(PO3), 1269(SA3), 1270(SA3), 1271(SA3), 1272(SA3), 1273(SA3), 1274(SA3), 1275(SA3), 1276(SA3), 1277(HY3), 1278(HY3), 1279(PL2), 1280(PL2), 1281(PL2), 1282(SA3), 1283(HY3)[c], 1284(PO3), 1285(PO3), 1286(PO3), 1287(PO3)[c], 1288(SA3)[c].

JULY: 1289(SM3), 1290(EM3), 1291(EM3), 1292(EM3), 1293(EM3), 1294(HW3), 1295(HW3), 1296(HW3), 1297(HW3), 1298(HW3), 1299(SM3), 1300(SM3), 1301(SM3), 1302(ST4), 1303(ST4), 1304(ST4), 1305(SU1), 1306(SU1), 1307(SU1), 1308(ST4), 1309(SM3), 1310(SU1)[c], 1311(EM3)[c], 1312(ST4), 1313(ST4), 1314(ST4), 1315(ST4), 1316(ST4), 1317(ST4), 1318(ST4), 1319(SM3)[c], 1320(ST4), 1321(ST4), 1322(EM3), 1323(AT1), 1324(AT1), 1325(AT1), 1326(AT1), 1327(AT1), 1328(AT1)[c], 1329(ST4)[c].

AUGUST: 1330(HY4), 1331(HY4), 1332(HY4), 1333(SA4), 1334(SA4), 1335(SA4), 1336(SA4), 1337(SA4), 1338(SA4), 1339(CO1), 1340(CO1), 1341(CO1), 1342(CO1), 1343(CO1), 1344(PO4), 1345(HY4), 1346(PO4)[c], 1347(BD1), 1348(HY4)[c], 1349(SA4)[c] 1350(PO4), 1351(PO4).

SEPTEMBER: 1352(IR2), 1353(ST5), 1354(ST5), 1355(ST5), 1356(ST5), 1357(ST5), 1358(ST5), 1359(IR2), 1360(IR2), 1361(ST5), 1362(IR2), 1363(IR2), 1364(IR2), 1365(WW3), 1366(WW3), 1367(WW3), 1368(WW3), 1369(WW3), 1370(WW3), 1371(HW4), 1372(HW4), 1373(HW4), 1374(HW4), 1375(PL3), 1376(PL3), 1377(IR2)[c], 1378(HW4)[c], 1379(IR2), 1380(HW4), 1381(WW3)[c], 1382(ST5)[c], 1383(PL3)[c], 1384(IR2), 1385(HW4), 1386(HW4).

OCTOBER: 1387(CP2), 1388(CP2), 1389(EM4), 1390(EM4), 1391(HY5), 1392(HY5), 1393(HY5), 1394(HY5), 1395(HY5), 1396(PO5), 1397(PO5), 1398(PO5), 1399(EM4), 1400(SA5), 1401(HY5), 1402(HY5), 1403(HY5), 1404(HY5), 1405(HY5), 1406(HY5), 1407(SA5), 1408(SA5), 1409(SA5), 1410(SA5), 1411(SA5), 1412(EM4), 1413(EM4), 1414(PO5), 1415(EM4)[c], 1416(PO5)[c], 1417(HY5)[c], 1418(EM4), 1419(PO5), 1420(PO5), 1421(PO5), 1422(SA5)[c], 1423(SA5), 1424(EM4), 1425(CP2).

NOVEMBER: 1426(SM4), 1427(SM4), 1428(SM4), 1429(SM4), 1430(SM4)[c], 1431(ST6), 1432(ST6), 1433(ST6), 1434(ST6), 1435(ST6), 1436(ST6), 1437(ST6), 1438(SM4), 1439(SM4), 1440(ST6), 1441(ST6), 1442(ST6)[c], 1443(SU2), 1444(SU2), 1445(SU2), 1446(SU2), 1447(SU2), 1448(SU2)[c].

DECEMBER: 1449(HY6), 1450(HY6), 1451(HY6), 1452(HY6), 1453(HY6), 1454(HY6), 1455(HY6), 1456(HY6)[c], 1457(PO6), 1458(PO6), 1459(PO6), 1460(PO6)[c], 1461(SA6), 1462(SA6), 1463(SA6), 1464(SA6), 1465(SA6), 1466(SA6)[c], 1467(AT2), 1468(AT2), 1469(AT2), 1470(AT2), 1471(AT2), 1472(AT2), 1473(AT2), 1474(AT2), 1475(AT2), 1476(AT2), 1477(AT2), 1478(AT2), 1479(AT2), 1480(AT2), 1481(AT2), 1482(AT2), 1483(AT2), 1484(AT2), 1485(AT2)[c], 1486(BD2), 1487(BD2), 1488(PO6), 1489(PO6), 1490(BD2), 1491(BD2), 1492(HY6), 1493(BD2).

VOLUME 84 (1958)

JANUARY: 1494(EM1), 1495(EM1), 1496(EM1), 1497(IR1), 1498(IR1), 1499(IR1), 1500(IR1), 1501(IR1), 1502(IR1), 1503(IR1), 1504(IR1), 1505(IR1), 1506(IR1), 1507(IR1), 1508(ST1), 1509(ST1), 1510(ST1), 1511(ST1), 1512(ST1), 1513(WW1), 1514(WW1), 1515(WW1), 1516(WW1), 1517(WW1), 1518(WW1), 1519(ST1), 1520(EM1)[c], 1521(IR1)[c], 1522(ST1)[c], 1523(WW1)[c], 1524(HW1), 1525(HW1), 1526(HW1)[c], 1527(HW1).

FEBRUARY: 1528(HY1), 1529(PO1), 1530(HY1), 1531(HY1), 1532(HY1), 1533(SA1), 1534(SA1), 1535(SM1), 1536(SM1), 1537(SM1), 1538(PO1)[c], 1539(SA1), 1540(SA1), 1541(SA1), 1542(SA1), 1543(SA1), 1544(SM1), 1545(SM1), 1546(SM1), 1547(SM1), 1548(SM1), 1549(SM1), 1550(SM1), 1551(SM1), 1552(SM1), 1553(PO1), 1554(PO1), 1555(PO1), 1556(PO1), 1557(SA1)[c], 1558(HY1)[c], 1559(SM1)[c].

MARCH: 1560(ST2), 1561(ST2), 1562(ST2), 1563(ST2), 1564(ST2), 1565(ST2), 1566(ST2), 1567(ST2), 1568(WW2), 1569(WW2), 1570(WW2), 1571(WW2), 1572(WW2), 1573(WW2), 1574(PL1), 1575(PL1), 1576(ST2)[c], 1577(PL1), 1578(PL1)[c], 1579(WW2)[c].

APRIL: 1580(EM2), 1581(EM2), 1582(HY2), 1583(HY2), 1584(HY2), 1585(HY2), 1586(HY2), 1587(HY2), 1588(HY2), 1589(IR2), 1590(IR2), 1591(IR2), 1592(SA2), 1593(SU1), 1594(SU1), 1595(SU1), 1596(EM2), 1597(PO2), 1598(PO2), 1599(PO2), 1600(PO2), 1601(PO2), 1602(PO2), 1603(HY2), 1604(EM2), 1605(SU1)[c], 1606(SA2), 1607(SA2), 1608(SA2), 1609(SA2), 1610(SA2), 1611(SA2), 1612(SA2), 1613(SA2), 1614(SA2)[c], 1615(IR2)[c], 1616(HY2)[c], 1617(SU1), 1618(PO2)[c], 1619(EM2)[c], 1620(CP1).

MAY: 1621(HW2), 1622(HW2), 1623(HW2), 1624(HW2), 1625(HW2), 1626(HW2), 1627(HW2), 1628(HW2), 1629(ST3), 1630(ST3), 1631(ST3), 1632(ST3), 1633(ST3), 1634(ST3), 1635(ST3), 1636(ST3), 1637(ST3), 1638(ST3), 1639(WW3), 1640(WW3), 1641(WW3), 1642(WW3), 1643(WW3), 1644(WW3), 1645(SM2), 1646(SM2), 1647(SM2), 1648(SM2), 1649(SM2), 1650(SM2), 1651(HW2), 1652(HW2)[c], 1653(WW3)[c], 1654(SM2), 1655(SM2), 1656(ST3)[c], 1657(SM2)[c].

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c. Discussion of several papers, grouped by divisions.